STATE OF NEW HAMPSHIRE
DEPARTMENT OF ENVIRONMENTAL SERVICES

WATER COUNCIL

NOTICE OF APPEAL
BY
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
780 North Commercial Street
Manchester, New Hampshire 03101

RECEIVED
JAN 19 2005

Re: Water Quality Certificate #2003-006
Dated as of December 16, 2004

05-01 WC

NOW COMES Public Service Company of New Hampshire ("PSNH") and respectfully states as follows:

BACKGROUND

PSNH owns and operates the Merrimack River Hydroelectric Project (the "Project") and proposes the continued operation of the Project for hydropower generation. The Project consists of the Garvins Falls, Hooksett and Amoskeag developments, all of which include a dam, powerhouse and project works such as turbines and generators. The Project extends from approximately one-half mile south of the breached Sewalls Falls dam in Concord, New Hampshire to the downstream end of the Amoskeag bypass reach, where the bypass reach rejoins the mainstem of the Merrimack River in Manchester, New Hampshire. The United States Federal Energy Regulatory Commission ("FERC") issued a license for the Project on May 8, 1980; that license expires on December 31, 2005.

In accordance with the Federal Power Act and related federal regulations, PSNH filed an application for a new license for the Project with the FERC on December 30, 2003. Section 401 of the United States Clean Water Act, 33 U.S.C. §1341, provides that applicants for a federal license which may result in a discharge into the navigable waters of the United States must obtain a certification from the State in which the discharge originates that any such discharge will comply with the applicable provisions of sections 301, 302, 303, 306 and 307 of the Clean Water Act (i.e. 33 U.S.C. §§1311, 1312, 1313, 1316 and 1317). Section 401 of the Clean Water Act also provides that States must act on 401 certificate applications within a reasonable period of time after receipt of such requests, which shall not exceed one year. If a state fails to act within the one year time period, the certification requirements of Section 401 are waived with respect to such Federal application. Any 401 conditions proposed after the one-year period are recommendations that the licensing agency has discretion to adopt, reject or modify. See, *Airport Communities Coalition v Graves*, 208 F. Supp. 2d 1207 (W.D. Wash. 2003).

Section 401 also requires that states shall establish procedures for public notice in the case of all applications for certification by it, and to the extent it deems appropriate, procedures for public hearings in connection with applications.

Pursuant to New Hampshire Department of Environmental Services ("NHDES") interim 401 water quality certificate regulations, Env-Ws 451-455, which became effective on December 6, 2003, PSNH filed its 401 certificate application dated December 16, 2003 and the filing was received by NHDES on December 17, 2003. PSNH's water quality certificate application, excluding the multi-volume federal license application and other materials attached thereto, is included in the Appendix attached hereto. In its filing, PSNH noted its reservation of right to argue that the relicensing of the Project did not result in a "discharge" requiring a 401 certificate.

New Hampshire Revised States Annotated 541-A:22, I provides that "no agency rule is valid or effective against any person or party, nor may it be enforced by the state for any purpose, until it has been filed as required under this chapter". NHDES water quality certificate interim regulations Env-Ws 451-455 expired on June 3, 2004 and new 401 water quality certificate regulations have not been issued. Nevertheless, by document dated as of December 16, 2004, NHDES purported to issue a 401 water quality certificate for the Project to PSNH. PSNH received an electronic copy of a document identified as the final 401 water quality certificate via electronic mail at 4:13 PM on Friday, December 17, 2004. A signed, paper copy of the certificate was mailed to PSNH postmarked December 21, 2004 and received on December 23, 2004. A copy of the signed, paper copy of the 401 certificate received by PSNH is included in the Appendix attached hereto.

SUMMARY OF APPEAL

I. NHDES IS WITHOUT AUTHORITY TO ISSUE A 401 WATER QUALITY CERTIFICATE BECAUSE THE FLOW OF WATER THROUGH THE PROJECT IS NOT A "DISCHARGE" OF "POLLUTANTS" SUBJECT TO CERTIFICATION UNDER SECTION 401

NHDES has acted contrary to law in issuing a Clean Water Act ("CWA") Section 401 certification dated as of December 16, 2004, in connection with the application of PSNH to the FERC for a new license for the Project. NHDES is without authority to issue such 401 certification because the flow of water through the Merrimack Project is not a "discharge" that is subject to certification under Section 401. Instead, water simply flows through the Project without the "addition" of a "pollutant" from a "point source."

CWA Section 401 certification only applies to activities that involve the "discharge" of a "pollutant" from a "point source." 33 U.S.C. §§1341, 1362(16). *Oregon Natural Desert Ass'n v. Dombeck*, 172 F.3d 1092 (9th Cir. 1998) (certification meant only to apply to point source releases and was not required for federal licenses that may cause pollution solely from nonpoint sources); *see PUD No. 1 of Jefferson County v. DOE*, 511 U.S. 700, 712 (1994) (Court did not address the question of what constitutes a discharge, but held that "§ 401(d) is more reasonably read as authorizing additional conditions and limitations on the activity as a whole once the threshold condition, the existence of a discharge, is satisfied") (emphasis added).

In *North Carolina v. FERC*, 112 F.3d 1175 (D.C. Cir. 1997), the D.C. Circuit held that a Section 401 certification from North Carolina was not needed because an intake structure designed to remove water from a project reservoir located in both Virginia and North Carolina for use in Virginia Beach would not result in a "discharge" at the project dam in North Carolina. The intake would only withdraw water and would not add anything to the project reservoir. The court concluded that "the word 'discharge' contemplates the addition, not the withdrawal, of a substance or substances," so the withdrawal of water would not result in a "discharge" for purposes of Section 401. *Id.* at 1187.

In *Alabama Rivers Alliance v. FERC*, 325 F. 3d 290 (D.C. Cir. 2003), the D.C. Circuit explained that the definitions of "discharge of a pollutant" and "discharges of pollutants" are "instructive as the nearest evidence we have of definitional intent by Congress" regarding the meaning of the term "discharge" under Section 401. *Id.* at 300 n. 12 (citation omitted). Therefore, the CWA and federal court precedent provide that Section 401 certification only applies to activities that involve the "discharge" and addition of a "pollutant" from a "point source" into "navigable waters."

On March 23, 2004, the U. S. Supreme Court decided that the transfer of water from one part of a water body to another part of the same water body does not constitute a "discharge of a pollutant." *South Florida Water Management District v. Miccosukee Tribe of Indians*, 124 S.Ct. 1537 (2004) ("*Miccosukee*"). In *Miccosukee*, a water management district operated a pumping facility that transferred water from a canal into a wetland area a short distance away. The Court remanded the case to the circuit court for determination of whether the canal and wetland area were "meaningfully distinct water bodies." If not, the Court held, the pump station would not require a CWA permit. *Id.* at 1547.

The flow of the water of the Merrimack River through the Project as proposed in the application for a new license is not a "discharge" subject to Section 401 certification. Instead, water simply flows through the project works with no "addition of any pollutant." 33 U.S.C. §1362(12). Moreover, PSNH has "proposed run-of-river operations throughout the new license term." (Certification at D-18d). Finding D-3 of the certification states that "The releases of water through Project structures and equipment, including but not limited to turbines and spillways, constitute a discharge under Env-Ws 1702.18."[1] However, the certification includes no evidence of a Project discharge as that term is defined under the CWA and relevant case law such as *Miccosukee, North Carolina v. FERC* and *Alabama Rivers Alliance.*. Instead, the 401

[1] In order for a discharge to be subject to State Section 401 authority it must meet the definition of "discharge" as defined in federal law in the CWA, not New Hampshire law. However, the State law definition of discharge in the December 16, 2004 certification is similar in many respects to the federal definition.

includes general statements regarding the impacts of dams generally on water quality. (D-6) [2] Therefore, NHDES is without authority to issue such certification.

II. NHDES IS WITHOUT AUTHORITY TO ISSUE A 401 WATER QUALITY CERTIFICATE BECAUSE NHDES HAS NO 401 CERTIFICATION REGULATIONS OR PROCEDURES IN EFFECT

A. Env-Ws 451-455

Even if there is a "discharge" from the Project subject to Section 401 certification, NHDES is without authority to issue such certification because it has no 401 certification procedures in effect. Section 401 requires that the agency that issues the certification adopt specific procedures for such certification. Specifically, "[s]uch State or interstate agency shall establish procedures for public notice in the case of all applications for certification by it and, to the extent it deems appropriate, procedures for public hearings in connection with specific applications." 33 U.S.C. §1341(a)(1).

The NHDES 401 Certification regulations Env-Ws 451-455 have lapsed, and as a result, NHDES has no definitions or other standards applicable to certificate issuance, no procedures for public notice and public hearings and no authority to issue a 401 certification under its own regulations or under the Clean Water Act. RSA 541-A:22, I clearly provides that an agency cannot apply regulations unless they have been adopted in accordance with applicable state law, and such requirement carries with it the necessary implication that such regulations cannot be applied if they have lapsed and are no longer in effect. No regulations were in place at the time of the issuance of the Section 401 water quality certificate to PSNH for the Merrimack hydroelectric project and, therefore, NHDES had no authority to issue the water quality certificate.

If it is determined that NHDES has authority to issue a 401 certificate under its lapsed regulations, NHDES failed to serve the document in accordance with Env-Wr 205.07, publicly notice the completion of the application and pending issuance of the certificate and to provide for public hearing as required by Env-Ws 454.03 and 454.04, and to follow other aspects of the regulations. As a result, NHDES has waived its authority to issue a 401 certificate in accordance with the provisions of 33 U.S.C. §1341. Additionally, NHDES has failed to demonstrate that there is any "discharge" of a "pollutant" as those terms are defined in Env-Ws 452 or that certification is required pursuant to Env-Ws 453.

B. Env-Wr 100-200

If NHDES has authority to issue a 401 water quality certificate under regulations other than Env-Ws 451-455, including under Env-Ws 1700, the general organization and

[2] In fact, the 401 concedes that the Merrimack River exceeds the numeric criteria for dissolved oxygen ("DO") and pH before river waters flow through the Project and contains no indication that the Project contributes to these exceedances or any violation of New Hampshire water quality standards through the "addition of any pollutant." 33 U.S.C. §1362(12).

procedural rules of the Department, Env-Wr 100-200 are applicable to such issuance. Env-Ws 205.07 provides that "All notices, orders, decisions or other documents issued by the division relative to this chapter shall be served by the division upon all parties to the proceeding in accordance with the following: (a) By deposition a copy of the document, certified mail return receipt requested postage paid, in the United States mails, addressed to the party at the last address given to the division by the party." NHDES failed to serve the water quality certificate on PSNH in accordance with these regulations within the one year period allowed by the Clean Water Act. *See, Appendix for copy of service envelope.* As a result, NHDES has waived its authority to issue a 401 certificate in accordance with the provisions of 33 U.S.C. §1341.

C. Env-Ws 1700

If NHDES has authority to issue a 401 certificate under regulations other than Env-Ws 451-455, the regulations upon which NHDES apparently relies, Env-Ws 1700, are inapplicable. Env-Ws 1701.02 provides that Env-Ws 1700 applies to any person who causes point or non-point source discharges of pollutants to surface waters, or who undertakes hydrologic modifications, such as dam construction or water withdrawals, or who undertakes any other activity that affects the beneficial uses or the level of water quality of surface waters. Continued operation the Merrimack hydroelectric project (i) does not cause point or non-point source discharges of pollutants to surface waters as those terms are defined in Env-Ws 1700, (ii) does not involve hydrologic modifications such as dam construction or water withdrawals, and (iii) does not affect the beneficial uses or the level of water quality of surface water.

III. THE 560 CFS BYPASS REACH FLOW ESTABLISHED FOR THE AMOSKEAG PROJECT IS ARBITRARY AND CAPRICIOUS AND NOT SUPPORTED BY SUBSTANTIAL EVIDENCE

Section E-5(c) of the Merrimack Water Quality Certificate establishes a bypass reach flow for the Amoskeag Project equal to (i) 410 cubic feet per second ("cfs") in the east channel, and (ii) the flow in the west channel corresponding to a 2.0 foot opening in the downstream fish bypass gate at full pond elevation, an amount equal to approximately 149.3 cfs, for a total bypass reach flow of 560 cfs. The "Second Addendum to the Evaluation of Instream Microhabitat Availability in the Bypass Reach of the Amoskeag Development on the Merrimack River, New Hampshire, Comparison of Flow Contributions to the West-Side Distributaries, dated October 2004, as revised November 2004" ("Second Addendum") provides data for three scenarios: the provision of flow to the west channel from (i) a 1.0 foot downstream bypass gate opening, equal to an estimated 58.1 cfs flow in the west channel, (ii) a 1.5 foot gate opening, equal to an estimated 115.0 cfs flow in the west channel, and (iii) a 2.0 foot gate opening, equal to an estimated 149.3 cfs flow in the west channel.

The scenario ordered in the Water Quality Certificate, the combination of 410 cfs from the dam crest, plus a 2.0 foot gate downstream fish bypass gate opening has not been analyzed. The Second Addendum at page 13 clearly indicates that provision of flow via both the bypass gate (i.e. sluice) and the spillway would likely result in conditions down the right side of transect 10 that differ from those that result from either source alone, because both avenues contribute flow to the western distributary from different directions. Thus, conditions on the right side of transect 10 resulting from the ordered flows are unknown. Based on results from other flows and areas of this complex environment, it is very possible that the combined flows required by the water quality certificate could result in an insignificant improvement over a 280 crest release with channel modification, the 410 crest release alone or a gate release alone, or even a comparative decrease in habitat, at a significant cost in generation as described herein.

IV. THE 560 CFS FLOW ESTABLISHED FOR THE AMOSKEAG PROJECT BYPASS REACH FLOWS IS UNLAWFUL AND UNREASONABLE BECAUSE THE REQUIREMENT FAR EXCEEDS THE STATUTORY OBLIGATION OF NHDES TO PROVIDE REASONABLE ASSURANCE THAT THE PROJECT COMPLIES WITH STATE WATER QUALITY STANDARDS

Section 401(d) provides that any certification shall set forth "any effluent limitation and other limitations ...necessary to assure that any applicant will comply with various provisions of the Act and appropriate state law requirements". Although Section 401(d) authorizes the State to place restrictions on the activity as a whole, that authority is not unbounded. The State can only assure that the Project complies with "any applicable effluent limitations and other limitations under 33 U.S.C. §§1311, 1312 or certain other provisions of the Act, and with any other applicable requirement of State law". The requirement that the Applicant provide bypass reach flows of approximately 560 cfs is well in excess of the flow necessary to assure compliance with applicable effluent limitations (if any) and other appropriate state law requirements.

The "Evaluation of Instream Microhabitat Availability in the Bypass Reach of the Amoskeag Development on the Merrimack River, New Hampshire, Addendum: Further Analysis Including Evaluation of Conditions at 410 CFS, dated July 2004" ("First Addendum") makes it clear that the vast majority of increase in habitat is provided at the crest flow of 150 cfs, some additional gains are achieved at the crest flow of 280 cfs, gains in most habitats and suitability top out at approximately 280 cfs, and gains in many habitats and in suitability decline at 410 cfs. *See, First Addendum at, inter alia, pages 16, 17, 22, 38-39 and 44.* Under these circumstance, requiring a bypass reach flow in excess of 150 cfs arguably exceeds the flow necessary to meet the statutory standard, the 280 cfs flow proposed by PSNH clearly meets the statutory standard and the flow of 560 cfs included in the water quality certificate is both unsupported by substantial evidence, and exceeds the statutory standard.

V. THE SECTION 401 CERTIFICATION IS UNLAWFUL AND UNREASONABLE BECAUSE THE CERTIFICATE REQUIREMENTS RESULT IN THE DEGRADATION OF AN EXISTING USE AND FAILS TO APPROPRIATELY BALANCE PRESERVATION OF EXISTING USES WITH PROTECTION OF SURFACE WATER QUALITY STANDARDS

NHDES regulations, Env–Ws 1708, establishes New Hampshire's anti-degradation policy in accordance with the Clean Water Act and EPA regulations at 40 C.F.R. 131.12. Env-Ws 1708.04 provides for the protection of existing uses of surface waters. "Existing uses" is defined by Env-Ws 1702.23 as "those uses, other than assimilation or waste transport, which actually occurred on the waterbody on or after November 28, 1975, whether or not they are included in the water quality standard." Use of the Merrimack River by the Project for hydroelectric generation is a use in existence on or after November 28, 1975.

The requirement for a minimum bypass reach flow of approximately 560 cfs in the Amoskeag development bypass reach violates the state's antidegradation policy by failing to properly balance the conflicting goals of preservation of the existing use of hydropower generation and the creation of additional habitat in the Amoskeag bypass reach. The increase in the Amoskeag bypass flow from the 150 cfs flow necessary to comply with applicable effluent limitations and other limitations under 33 U.S.C. §§1311, 1312, 1313 and with any other applicable requirement of State law to the approximately 560 cfs bypass reach flow required by the Water Quality Certificate results in increased costs to PSNH's retail customers of between approximately $200,000 to $440,000 annually during the license period, and approximately $11 million over a projected 40 year license term.

Loss of the existing use of this magnitude should only be required in connection with substantial, as opposed to minimal, gains in habitat. The evidence in the record and reasonable assumptions based thereon demonstrates that a total bypass reach flow of approximately 150 cfs (which could be coupled with modifications to Pool 4 to provide an additional 30 cfs to Ripple 16), will clearly achieve compliance with state water quality standards and adequately protect existing and designated uses. At this bypass reach flow, bank to bank watering of a majority of the bypass reach is achieved; a diverse habitat including riffles, pools, runs and cascades is created; shallow-coarse, shallow-slow, deep-fast, slow-cover, and shallow-fast habitats are well represented, an increase in weighted usable area to approximately 147,864.78 is achieved. At the 280 cfs flow proposed by PSNH, additional gains, not required by the applicable standard, are achieved, and at increasing flows in the range of 410 cfs, losses in some areas begin to offset gains in others.

Appropriate balancing of the limited gain in habitat associated with the increased flows is particularly important because the increased monetary and environmental cost associated with replacement of this hydroelectric generation with more expensive and less environmentally friendly nuclear, coal or gas fired generation, as well as the other intangible costs associated with replacement of renewable generation with non-renewable generation, will be born by New Hampshire residents and PSNH customers. The creation of an estimated 16,791 pounds of additional greenhouse gases annually will result from loss of this renewable resource, for a total of 671,632 pounds over a projected 40 year license term. As noted above, this is coupled with an estimated revenue loss of $11 million.

VI. THE SECTION 401 CERTIFICATION IS UNLAWFUL BECAUSE IT PURPORTS TO RESERVE AUTHORITY TO NHDES TO ADD OR ALTER CONDITIONS DURING THE LIFE OF THE LICENSE, VIOLATING THE PLAIN TEXT OF THE CLEAN WATER ACT AND THE FEDERAL POWER ACT

Further, the Section 401 certification is unlawful because it purports to reserve authority to NHDES to add or alter conditions during the life of the license, violating the plain text of the CWA which provides for a one-year deadline to establish such conditions, and the Federal Power Act, which provides that only the FERC may amend a license after it has been issued. Further, Conditions E-9 and E-10 unlawfully reserve authority for NHDES to add or alter certification terms during the life of the license. This violates the plain text of the CWA, which provides that certification is a one-time occurrence, and is waived if the certifying agency does not act within one year of an application for certification. 33 U.S.C. §1341.

Conditions E-9 and E-10 also violate EPA regulations which provide that, "[t]he certifying agency may modify the certification in such manner as may be agreed upon by the certifying agency, the licensing or permitting agency, and the Regional Administrator." 40 C.F.R. § 121.2(b). Therefore, this certification may only be amended if NHDES obtains the agreement of the licensing agency, FERC, and EPA Region 1. NHDES is without authority to unilaterally modify the terms of the certification. These conditions are also contrary to *Airport Communities Coalition v Graves*, 208 F. Supp. 2d 1207 (W.D. Wash. 2003) (all 401 terms added after the one-year period are advisory, not binding).

Condition 6 also is an unlawful infringement on FERC's comprehensive licensing authority under the Federal Power Act. *First Iowa Hydro-Electric Cooperative v. FPC*, 328 U.S. 152 (1946); *California v. FERC*, 495 U.S. 490 (1990). Moreover, Section 6 of the FPA provides that a hydroelectric license "may be altered or surrendered only upon mutual agreement between the licensee and the Commission after thirty days public notice." 16 U.S.C. §799. Only FERC and the licensee by "mutual agreement" may modify the terms and conditions of a hydroelectric license once it has been issued.

VII. THE 401 CERTIFICATE IS ARBITRARY AND CAPRICIOUS AND NOT SUPPORTED BY SUBSTANTIAL EVIDENCE IN THAT CERTAIN FINDINGS ARE INCORRECT, INCOMPLETE OR ARE USED TO SUPPORT IMPLICATIONS NOT ESTABLISHED BY EVIDENCE OF CAUSATION

The Water Quality Certificate includes findings that are incorrect, incomplete or not established by evidence of causation, including, but not limited to, the items set forth in more detail below:

a. Finding D-1 is incomplete in that it fails to identify the Project as an existing use. The Project was in operation prior to 1975 and is an existing use as defined in Env-Ws 1708.04. Protection of this existing use should be balanced with other, competing water quality goals.

b. The D-5 finding that "These conditions (i.e., the presence of dams and the creation of impoundments) promote variable water quality conditions, particularly regarding water temperature, dissolved oxygen, pH and nutrients" is vague and not supported by substantial evidence, especially to the extent that it relates specifically to the Project, and should be deleted.

c. The D-5 conclusion that "In addition, the regulated river flows from the Project influence the river flows downstream to and beyond the NH-MA state boundary" is incorrect, unnecessary and should be stricken. When operated in run-of-river mode as proposed by PSNH, the influence of the Project on downstream flows is negligible. Such negligible effects are overshadowed by the effects of flood control projects, any hydroelectric facilities not operated in run-of-river mode and other water diversions and are neither measurable nor discernable at the NH-MA state boundary, many miles downstream.

d. The conclusion implied from finding D-6 that hydroelectric power generation indirectly contributes to pH changes is unsupported by substantial evidence. A much more likely cause of any pH changes observed by the Department are discharges from sewage treatment plants and other point and non-point source discharges. To the extent that the D-6 statement that "The Department analyzed nutrient data from impounded waterbodies included but not limited to chlorophyll a, to review the effect of Project operations on water quality" purports to determine conditions in the Project area from non-Project data, such action is arbitrary and capricious.

e. To the extent that the D-6 findings imply that determination of water quality is appropriately made under extreme conditions of low river flow and high temperature, rather than under normally occurring conditions (i.e. "...the Department analyzed surface water quality data collected by the Applicant under these conditions" and did not consider the significant amount of other Project area data in the Department's possession reflective of average conditions), such finding is unlawful, unreasonable, arbitrary and capricious and not supported by substantial evidence. There is no legal requirement that compliance be based on extreme conditions, the Department does not routinely require that determinations be made under such conditions and imposition of such a standard with respect to the Project is unlawful, unreasonable, arbitrary and capricious and not supported by substantial evidence.

f. The D-7 statement that "The Department acknowledges that the water quality data collected by the Applicant adequately represented the Merrimack River under near limiting conditions" is vague and unclear. As noted above, to the extent that the statement is intended to suggest determinations are legally required to be made under extreme conditions of river flows and temperature and that the 2002-2003 data was adequate for this purpose and other data in the Department's possession representative of average conditions can be ignored, the statement is unlawful and unreasonable. If the statement is intended to acknowledge that the water quality data collected during 2002-2003 reflected worst case, or near worst case (i.e. near limiting) conditions, it should clearly state that this is the case.

g. The Department's use, in finding D-8, of limited data points occurring during extreme low flow and high temperature periods, and failure to use other data within the Department's knowledge and possession, to imply continuously occurring non-compliance with state water quality standards within the Project area, and causation resulting from either the Project or Merrimack Station is unlawful, unreasonable, arbitrary and capricious and not supported by substantial evidence. The sentence regarding the Department's expectation that any water temperature concerns associated with the discharge from the Merrimack Station facility will be addressed through the NPDES permitting process is not germane to the 401 water quality certificate for the Project and should be stricken.

h. The D-13(f) finding that the various benthic macro invertebrate groups and life stages of fishes "require the diverse habitat offered in the Amoskeag bypass reach" is arbitrary and capricious and not supported by substantial evidence. As correctly noted at the beginning of the sentence, these groups and fishes represent common aquatic biota in the Merrimack River generally. While humans may believe that they "prefer" such habitat, they do not "require" the habitat offered in the bypass reach, or they could not represent common biota in the river generally.

i. The D-13(f) finding that the habitat composition was most diverse under the 410 cfs bypass reach flow is arbitrary and capricious and contradicted by the record evidence. The 150, 280, and 410 flows all included appreciable amounts of shallow-coarse, shallow-slow, deep-fast, slow-cover and shallow-fast habitat.

j. The D-13(f) finding that the habitat connectivity achieved under the 410 cfs river flow augmented habitat diversity and complexity necessary to support aquatic life is arbitrary and capricious and not supported by substantial evidence. Bank to bank watering and reasonable habitat connectivity were achieved over most of the bypass reach at flows of 150 and 280 cfs, as demonstrated by the flow study video tapes. There was no "augmentation" of diversity or complexity resulting from higher flows. All habitat types were present at flows of 150 and 280 cfs. The "complexity" of the area did not increase as a result of increasing flows – riffles, pools, runs and cascades and all habitat types were present at all flows of 150 cfs and 280 cfs, as well as 410 cfs.

k. The E-3 requirement that "The Applicant shall participate in any Total Maximum Daily Load ("TMDL") study of the Merrimack River that includes any portion of the Merrimack River within the Project boundary" and that "Participation includes, but is not limited to, assistance with monitoring or dam operation to facilitate development of the TMDL" is vague and unclear. To the extent that it purports to impose upon PSNH the obligation to fund or otherwise participate in TMDL studies in excess of any PSNH contribution that would otherwise be required under applicable statutes and regulations regarding TMDL, it is unlawful and unreasonable.

l. The E-6 and E-7 requirements that PSNH complete certain activities prior to a date certain should be restated to tie the requirement to a time period following issuance of the FERC license. PSNH's obligation to obtain a water quality certificate results from its obligation to obtain a FERC license, and the water quality certificate should not take effect prior to the issuance of a new FERC license.

m. The D-13(h) finding that only 10 cfs of the 75 cfs crossover flow at 410 cfs between the east and west channel was provided through the southern part of the west channel (i.e. Riffle 16) is incorrect and contradicted by the record evidence. The Second Addendum, page 5, Figure 2, "Flow Split at Transect 10 – Crest Only, Bypass Closed" shows that of the 75 cfs crossover flow, roughly 10 cfs is provided to the northern part of the west channel (i.e. Riffle 15) and roughly 65 cfs is provided to the southern part of the west channel (i.e. Riffle 16).

n. The D-16 finding that the Merrimack River supports the Atlantic salmon as a migratory fish in the vicinity of the Project is arbitrary and capricious and not supported by substantial evidence. In its current state, including the existence of flood control facilities which significantly impact the spring freshet and other related flood events and the existence of downstream dams, the Merrimack River does not support any naturally occurring Atlantic salmon in the vicinity of the Project. USFWS has coordinated a restoration program for salmon, but restoration of an Atlantic salmon population in the vicinity of the Project has not materialized.

o. The statement in the Water Quality Certificate "Introduction" that "The Project extends south from the breached Sewalls Falls dam to the downstream end of the Amoskeag bypass reach where the bypass reach rejoins the mainstem Merrimack River" is incorrect and should be corrected. As indicated in PSNH's license application, Volume XII (containing Critical Energy Infrastructure Information), final page, the Project extends from approximately one-half mile south of the breached Sewalls Falls dam to the end of the Amoskeag bypass reach.

WHEREFORE, PSNH respectfully requests that the Water Council:

A. Declare Water Quality Certificate #2003-006 null and void on the grounds that the 401 Water Quality Certificate regulations have lapsed, were not in effect when the Water Quality Certificate was issued, and RSA 541-A:22, I provides that an agency cannot apply regulations unless they have been adopted in accordance with applicable state law, and such requirement carries with it the necessary implication that such regulations cannot be applied if they have lapsed and are no longer in effect. Additionally, NHDES failed to serve the document as required by Env-Wr 205.07 within the one year period allowed by the Clean Water Act. As a result, NHDES has waived its authority to issue a 401 certificate in accordance with the provisions of 33 U.S.C. §1341.

B. Declare Water Quality Certificate #2003-006 null and void on the grounds that the Clean Water Act does not, in and of itself, permit the issuance of a water quality certificate in the absence of procedures and regulations, and the state either (i) had no applicable procedures or regulations in effect at the time the certificate was issued, (ii) failed to follow any regulations deemed to be applicable and effective, or (iii) any effective regulations are inapplicable, as discussed in Section II and other sections above.

C. Determine that Water Quality Certificate #2003-006 is not required because the operation of the Merrimack River hydroelectric project does not result in a "discharge" of "pollutants" under the Clean Water Act and any applicable state law or regulations.

D. In the alternative, if Water Quality Certificate #2003-006 is not declared null and void as requested herein, modify the certificate to specify a bypass reach flow at the Amoskeag development of 280 cfs and make such other corrections and modifications thereto as noted above.

E. Schedule a pre-hearing conference to determine whether the matter can be resolved without the need for a formal hearing, and if necessary, schedule a hearing with respect to all matters raised herein, and

F. For such other relief as is just and equitable.

Dated: January 18, 2005.

Respectfully Submitted,
PUBLIC SERVICE COMPANY OF
NEW HAMPSHIRE
By its Attorney,

Catherine E. Shively
Northeast Utilities Service Company
780 North Commercial Street
Manchester, New Hampshire 03101
(603) 634-2326

CERTIFICATION

I hereby certify that on January 18, 2005, I have caused to be hand delivered a copy of PSNH's "Notice of Appeal" set forth above to Harry T. Stewart, P.E., Director, Water Division and Michael P. Nolin, Commissioner, New Hampshire Department of Environmental Services.

COPY

Catherine E. Shively

<u>APPENDIX</u>

1. PSNH'S Water Quality Certification Application and Cover Letter;
2. Signed copy of Water Quality Certification;
3. Second Addendum ("Second Addendum")
4. Evaluation of Instream Microhabitat ("First Addendum")

Public Service
of New Hampshire

PSNH Energy Park
780 North Commercial Street, Manchester, NH 03101

Public Service Company of New Hampshire
P.O. Box 330
Manchester, NH 03105-0330
(603) 669-4000
www.psnh.com

The Northeast Utilities System

December 16, 2003

Dept. of Environmental Services
6 Hazen Drive,
PO Box 95,
Concord, New Hampshire 03302-0095

RECEIVED
DEC 17 2003
DEPARTMENT OF ENVIRONMENTAL SERVICES
PP

Attn: Paul Piszczek

Re: Merrimack River Hydroelectric Project

Dear Paul:

Attached please find Public Service Company of New Hampshire (PSNH's) application for 401 Water Quality Certificate for the Merrimack River Hydroelectric Project (FERC No. 1893-NH). As we discussed, the attached filing includes all of the requisite additional submittal information except for a copy of PSNH's Final FERC License Application, which we agreed would be subsequently filed with the FERC and your office by 12/31/03.

If you have any questions concerning this filing, please contact Curt Mooney at 744-8855 Ext. 11.

Very truly yours,

COPY

James Kearns
Project Manager

Enclosures

OS6161 REV. 01-00

State of New Hampshire
DEPARTMENT OF ENVIRONMENTAL SERVICES
6 Hazen Drive, PO Box 95, Concord, New Hampshire 03302-0095
Phone (603) 271-2457 Fax (603) 271-7894

APPLICATION FOR 401 WATER QUALITY CERTIFICATE

1. APPLICANT INFORMATION:

Name of Applicant Public Service Company of New Hampshire

Address P.O. Box 330

City/Town Manchester Zip 03105 Phone # (603) 744-8855 Ext. 11

Principal Place of Business 780 North Commercial Street, Manchester, NH 03101

2. PROJECT INFORMATION
[Note: Project information listed separately for each of the three developments]

(a) Name of Project Merrimack River Hydroelectric Project – Garvins Falls Development

Address Garvins Falls Road

City/Town Bow County Merrimack

Receiving Stream Merrimack River

Drainage Basin Merrimack River Basin, HUC 01070006

Description of Project The Garvins Falls Development, located on the Merrimack River at river mile 86.8, is the most upstream station of the three facilities comprising the Merrimack River Hydroelectric Project. The dam consists of two spillway sections and the reservoir pool extends upstream about 8 miles, almost to Sewalls Falls dam and has a contributing drainage area of 2,427 square miles. The powerhouse contains four turbines, the discharge is released downstream of the dam into the Merrimack River.

(b) Name of Project Merrimack River Hydroelectric Project – Hooksett Development

Address Merrimack Street

City/Town Hooksett County Merrimack

Receiving Stream Merrimack River

Drainage Basin Merrimack River Basin, HUC 01070006

Description of Project The Hooksett Development, located on the Merrimack River at river mile 81.1 downstream of the Garvins Falls Development, has a drainage area of 2,805 square miles. The reservoir pool extends upstream about 5.5 miles. The powerhouse contains a single turbine, the discharge is released downstream of the dam into the Merrimack River.

(c) Name of Project Merrimack River Hydroelectric Project – Amoskeag Development

Address Fletcher Street

City/Town Manchester County Hillsborough

Receiving Stream Merrimack River

Drainage Basin Merrimack River Basin, HUC 01070006

Description of Project The Amoskeag Development, located on the Merrimack River at river mile 73.2, is the most downstream station of the three facilities comprising the Merrimack River Hydroelectric Project. The dam length is approximately 710 feet and the reservoir pool extends upstream to the Hooksett Dam. The contributing drainage area at the Amoskeag Dam is 2,854 square miles. The powerhouse, located on the west end of the dam, contains three turbines which discharge downstream into the Merrimack River.

Project Schedule:

Beginning of Construction N/A

End of Construction N/A

Operation Period N/A

Name of Person Responsible for Project Curtis R. Mooney, PSNH Hydro

Phone # (603) 744-8855 Ext. 11

3. DISCHARGE INFORMATION
[Note: Discharge information listed separately for each of the three developments]

Garvins Falls Development

Is the discharge occurring or proposed? Occurring*

Latitude/Longitude of discharge N 43 9.86 00 / W 071 30.4466

Name of Receiving Water Merrimack River

County Merrimack

Drainage Basin Merrimack River Basin, HUC 01070006

Hooksett Development

Is the discharge occurring or proposed? Occurring*

Latitude/Longitude of discharge N 43 6.0610 / W 071 27.9216

Name of Receiving Water Merrimack River

County Merrimack

Drainage Basin Merrimack River Basin, HUC 01070006

Amoskeag Development

Is the discharge occurring or proposed? Occurring*

Latitude/Longitude of discharge N 43 0.1194 / W 071 28.3483

Name of Receiving Water Merrimack River

County Hillsborough

Drainage Basin Merrimack River Basin, HUC 01070006

* By applying for a 401 water quality certificate, PSNH explicitly reserves and does not waive its right to argue that operation of the Merrimack River Project does not result in a discharge requiring a permit pursuant to Env-Ws 453.01(a), and/or that the renewal of its federal license does not result in an increased discharge to the surface water of the state or a change in the quality of the discharge Env-Ws 453.02.

4. ADDITIONAL SUBMITTAL INFORMATION

- An original of a United States Geological Survey Quadrangle Map with the location of the project and its discharge; *(Three separate maps attached)*
- Copy of the complete federal permit application, including federal permit number; *(Copy of 401 application must be included in the Final FERC License Application. Copy of Final License Application will be filed with NHDES and FERC by 12/31/03)*
- Copy of the wetlands permit; (*None*)
- Copy of the alteration of terrain permit (RSA 485-A:17); (*None*)
- Copy of any other state and local permits and application required by law; (NPDES Permit Nos. Amoskeag Hydro – NH0001392, Hooksett Hydro – NH0001422 & Garvins Falls Hydro – NH0001406. Copies of permits attached.)
- Name and addresses of adjoining riparian or littoral owners; *(P. Piszczek of NH DES agrees to waive this requirement.)*

- Plan showing the proposed project to scale including: *(Maps showing the FERC Project Boundary, and the locations of the existing structures are contained in the Final License Application, Exhibit G. Exhibit G is Critical Energy Infrastructure Information ("CEII".) Procedures for obtaining access to CEII may be found at 18 CFR 388.113. Requests for CEII should be made to the Federal Energy Regulatory Commission's CEII Coordinator.*

  - Project Boundaries;

  - Location, dimensions and types of any existing and/or proposed structures; and

  - Location and extent of water bodies, including wetlands. *(Wetlands in the Project area were mapped and the report entitled "Merrimack River Hydroelectric Project Amoskeag, Hooksett and Garvins Falls Wetland Resources" containing this information is located in Final License Application, Volume VII)*

Signature – <u>MUST</u> BE SIGNED AND DATED BY APPLICANT

To the best of my knowledge, the data and information, which, I have submitted to the New Hampshire Department of Environmental Services, is true and correct. I understand that an approval based upon incorrect data may be subject to revocation. I have complied with all local regulations or ordinances relative to this project and have obtained or will obtain, prior to the commencement of any work, all other approvals that may be required.

Date: Dec. 16, 2003 **Signed:**

COPY

Public Service Company of New Hampshire
Attn: Robert Gunderson, Hydro Manager
PSNH Energy Park
780 North Commercial Street
Manchester, NH 03101

NOTED

DEC 2 3 2004

GUNDERSEN

WATER QUALITY CERTIFICATION

In Fulfillment of

Section 401 of the United States Clean Water Act (33 U.S.C 1341)

WQC # 2003-006

Project Name:	Merrimack River Hydroelectric Project
Project Location:	Concord, Hooksett, and Manchester, New Hampshire
Affected Waterbody:	Merrimack River
Owner/Applicant:	Public Service Company of New Hampshire 780 North Commercial Street Manchester, NH 03101
Appurtenant License:	Federal Energy Regulatory Commission No. P-1893
DATE OF APPROVAL: (subject to Conditions below)	December 16, 2004

A. INTRODUCTION

Public Service Company of New Hampshire (Applicant) owns and operates the Merrimack River Hydroelectric Project (Project) and proposes the continued operation of the Project for hydropower generation.

The Project consists of the Garvins Falls, Hooksett, and Amoskeag developments, all of which include a dam, powerhouse, and Project works such as turbines, generators, transmission lines, etc. The Project extends south from the breached Sewalls Falls dam to the downstream end of the Amoskeag bypass reach where the bypass reach rejoins the mainstem Merrimack River. The U.S. Federal Energy Regulatory Commission (Commission) issued a license for the Project on May 8, 1980; the license expires on December 31, 2005.

This 401 Water Quality Certification (Certification) documents laws and regulations, determinations, and 401 Certification conditions relative to the attainment/maintenance of NH surface water quality standards defined under NH RSA 485-A:8 II, which includes the support of designated uses defined under NH Code of Administrative Rules Env-Ws 1700.

with the applicable provisions of sections 301, 302, 303, 306, and 307 of this title.

C-4. Clean Water Act Section 401(a) states "[n]o license or permit shall be granted until the certification required by this section has been obtained or has been waived...No license or permit shall be granted if certification has been denied by the State..."

C-5. Clean Water Act Section 401(a) authorizes the Department to verify that the Project maintains compliance with NH surface water quality standards.

C-6. Env-Ws 1700, Surface Water Quality Regulations, effective December 3, 1999, fulfills the requirements of Section 303 that the State of New Hampshire adopt water quality standards consistent with the provisions of the Clean Water Act.

C-7. Env-Ws 1701.02 provides that the surface water quality regulations shall apply to all surface waters and to any person who causes point or nonpoint source discharge(s) of pollutants to surface waters, or who undertakes hydrologic modifications, such as dam construction or water withdrawals, or who undertakes any other activity that affects the beneficial uses or the level of water quality of surface waters.

C-8. Env-Ws 1702.18 defines a discharge as:

a. (1) The addition, introduction, leaking, spilling, or emitting of a pollutant to surface waters, either directly or indirectly through the groundwater, whether done intentionally, unintentionally, negligently, or otherwise; or

b. (2) The placing of a pollutant in a location where the pollutant is likely to enter surface waters.

C-9. Env-Ws 1702.39 defines pollutant as dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, (except those regulated under the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq.)), heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

C-10. Env-Ws 1702.46 defines surface waters as "perennial and seasonal streams, lakes, ponds and tidal waters within the jurisdiction of the state, including all streams, lakes, or ponds bordering on the state, marshes, water courses and other bodies of water, natural or artificial," and waters of the United States as defined in 40 CFR 122.2.

C-11. Env-Ws 1703.01 (c) states that "[a]ll surface waters shall provide, wherever attainable, for the protection and propagation of fish, shellfish and wildlife, and for recreation in and on the surface waters."

C-12. Env-Ws 1703.01 (d) states that "[u]nless the flows are caused by naturally occurring conditions, surface water quantity shall be maintained at levels adequate to protect existing and designated uses."

three impoundments, three bypass reaches, and three tailraces. In addition, the regulated river flows from the Project influence the river flows downstream to and beyond the NH-MA state boundary. The impoundments, bypass reaches, and tailraces are created by the presence of the Garvins Falls, Hooksett, and Amoskeag developments. The presence of dams and the subsequent creation of impoundments at each development reduces water velocities and increases river residence time beyond that which occurs under unimpounded conditions. These conditions promote variable water quality conditions, particularly regarding water temperature, dissolved oxygen, pH, and nutrients. In addition, the diversion of water through Project penstocks during hydroelectric power generation reduces the quantity of water available to bypass reaches.

D-6. The primary chemical water quality concerns of the Department for waterbodies affected by hydroelectric power generation included dissolved oxygen and pH, which are the primary chemical indicators for assessing non-wadeable rivers and streams relative to the support of aquatic life. The Department also analyzed nutrient data from impounded waterbodies including, but not limited to, chlorophyll *a* to review the effect of Project operations on water quality. The Department recognizes that the ambient water quality conditions of rivers, streams, and impoundments in New Hampshire are typically lowest during periods of seasonally low river/stream flow rates and warm ambient air and water temperatures that typically occur during, but not limited to, mid-late summer. To the extent practicable, the Department analyzed surface water quality data collected by the Applicant under these conditions to assess the support of aquatic life by the waterbody.

D-7. The Applicant studied the water quality of the Merrimack River from the breached Sewalls Falls Dam to the Amoskeag tailrace during 2002-2003 to address the water quality concerns raised by the Department and other resource agencies during the pre-filing consultation period. Water temperatures at the inflow to the Project area (Sewalls Falls) ranged from 21-28°C during July and August 2002 and from 18-26°C during September 2002. River flows in the Project area from July 15-October 1, 2002 ranged from 632-1,510 cubic feet per second (cfs) near the Amoskeag development and from 445-1,096 cfs near Sewalls Falls. The 7Q10 flows near Amoskeag and Sewalls Falls approximate 650 cfs and 620 cfs, respectively. The Department acknowledges that the water quality data collected by the Applicant adequately represented the Merrimack River under near-limiting conditions.

D-8. The Applicant measured water temperature and dissolved oxygen in the water column of Garvins Falls, Hooksett, and Amoskeag impoundments during 2002. On June 25, 2002, the water temperatures were 5°C greater in the Hooksett impoundment than in the Garvins Falls impoundment, and on July 25-26, 2002 and August 22-23, 2003, the water temperatures were 3-4°C greater in the Hooksett impoundment than in the Garvins Falls impoundment. The Hooksett and Garvins Falls impoundments experienced thermal stratification on July 26, 2002, but the magnitude of stratification was higher in the Hooksett impoundment. During both sampling dates, only the Hooksett impoundment experienced chemical (dissolved oxygen) stratification. The Merrimack Station, riverine environments not inundated by impoundments in the entire Merrimack River. The channels were collectively divided into an east channel and a west channel relative to the geomorphologic and hydraulic characteristics of the individual channels. The west channel was further divided into a northern and southern segment, and represented by riffle 15 and riffle 16, respectively, as shown on the Amoskeag Dam Bypass Habitat Map dated October 9, 2002.

c. A multi-scale (meso-scale and micro-scale) survey of available aquatic habitats was conducted due to the size and complexity of the bypass reach. The survey was conducted to define the primary aquatic habitat types such as pools, riffles, and cascades and to identify potential sources of controlled and uncontrolled discharges usable for aquatic habitat augmentation. The bypass reach contained 17.96 surface acres of aquatic meso-habitat. Riffles, pools, and runs/cascades represented 54%, 28%, and 18% of the habitat, respectively. Under existing conditions, water in the east channel is conveyed from the dam through leakage and spillage, and water in the west channel is conveyed from the downstream fish bypass structure and from the dam under various river flow conditions.

d. The aquatic habitat types were quantitatively analyzed in additional detail as a component of the micro-scale survey. The survey incorporated elements of the Instream Flow Incremental Methodology (IFIM), including the establishment of transects perpendicular to river flow to determine stream bed substrates and water column depths and velocities. The aquatic habitat types were quantitatively analyzed relative to the availability of suitable habitat for various benthic macroinvertebrate groups (Ephemeroptera, Plecoptera, and Trichoptera) and life stages of various fishes (smallmouth bass, longnose dace, common shiner, fallfish, and blueback herring). These groups and fishes represent common aquatic biota in the Merrimack River that require the diverse habitats offered in the Amoskeag bypass reach.

e. The micro-scale survey included the evaluation of aquatic habitats under four river flow rates (50, 150, 280, and 410 cfs). Empirical data were collected from 10 transects established throughout the bypass reach to represent the available aquatic habitats in the bypass reach.

f. The composition and distribution of aquatic habitats under the four river flow rates (50, 150, 280, and 410 cfs) were identified and categorized as shallow-coarse, shallow-slow, deep-fast, slow-cover, and shallow-fast. The habitat categories are commonly used in instream flow studies to represent the aquatic habitat typically used by aquatic biota. The habitat composition was most diverse under the 410 cfs river flow. The amount of deep-fast and shallow-fast habitats under the 410 cfs river flow allows for turbulent aeration of surface waters in the bypass reach. The habitat connectivity achieved under the 410 cfs river flow augmented the habitat diversity and complexity necessary to support aquatic life. The development of balanced, integrated aquatic biological communities is dependent on the presence and availability of diverse aquatic habitats.

g. Weighted useable area (WUA) is a common measure used in instream flow studies to represent the aquatic habitats available to aquatic biota. Of the filing consultation period. In addition, the Applicant evaluated flow releases through the downstream fish bypass reach.

a. A meso-scale survey of available aquatic habitats was conducted to define the primary aquatic habitat types such as pools, riffles, and cascades and to identify potential sources of controlled discharges usable for augmentation of aquatic habitat. The mainstem bypass reach contained 2.5 surface acres of aquatic meso-habitat. Deep runs, pools and cascades, wetted ledges, and riffles represented 53%, 22%, 19%, and 6% of the habitat, respectively.

b. The Applicant and agencies observed various water release configurations from Project structures and corresponding river flow rates in the mainstem and downstream fish bypass reaches to determine the appropriate flow distribution and minimum flow rate through the bypass reaches. Sufficient aquatic habitat was created in the mainstem bypass reach under a 55 cfs flow rate and in the downstream fish bypass reach under a 23 cfs flow rate. The flow rate in the mainstem bypass reach was achieved through the removal of one flashboard at the middle of the dam plus leakage through the dam at full pond elevation (as configured during a site visit on July 15, 2003). The flow rate in the downstream fish bypass reach was achieved through a one-foot opening in the fish bypass gate at full pond elevation.

D-16. The Merrimack River supports migratory fishes such as alewife, American eel, Atlantic salmon, American shad, and blueback herring. The U.S. Fish and Wildlife Service (USFWS) and the New Hampshire Fish and Game Department (NH F&G) manage Atlantic salmon in the Merrimack River and its tributaries. USFWS has coordinated a restoration program for salmon and other migratory fishes since 1976. The Cooperative Interstate and Federal Policy and Technical Committees are the decision-making entities relative to restoration.

D-17. A comprehensive plan was developed in 1986 by the Applicant and the Policy and Technical Committees for Anadromous Fishery Management on the Merrimack River for providing anadromous fish passage at hydroelectric facilities on the Merrimack River and Pemigewasset River, including the Amoskeag, Hooksett, and Garvins Falls developments. Upstream and downstream fish passage facilities for anadromous fishes were subsequently created at the Amoskeag development and downstream passage facilities were created at the Garvins Falls and Hooksett developments. The Applicant studied the effectiveness of the passage facilities from 1986 through 2004 relative to alewife, American eel, American shad, Atlantic salmon, and blueback herring and found variable results.

D-18. The Applicant operates the Project in a limited store-and-release mode, except during periods of low river flow when the developments are operated in run-of-river mode.

a. The water surface elevations of the Garvins Falls impoundment experienced average daily fluctuations from 0.5-1.0 feet on a daily basis, but occasional fluctuations up to three feet have occurred during the past several years. The water surface elevations of the Amoskeag impoundment experienced average daily fluctuations from 1.0-1.5 feet, but occasional fluctuations up to

c. Amoskeag: 833 cfs or inflow, whichever is lower.

E-5. Unless otherwise permitted in the approved operations plan, and upon implementation of the approved operations plan as described in section E-7 of this 401 Certification, the Applicant shall, at all times, provide minimum flow releases in Project bypass reaches for the protection of aquatic life, as follows:

a. Garvins Falls: 55 cfs in the mainstem bypass and 23 cfs in the downstream fish bypass channel;

b. Hooksett: 64 cfs; and

c. Amoskeag: 410 cfs in the east channel and the flow in the west channel corresponding to a 2.0-foot opening in the downstream fish bypass structure at full pond elevation. The Applicant shall confirm the flow rate from the 2.0-foot opening that occurred on September 30, 2004 for the purpose of evaluating aquatic habitats in the west channel.

E-6. The Applicant shall evaluate the ability of the developments to maintain constant water surface elevations and/or constant downstream flows during times of daily power generation. The evaluation shall include, but not be limited to, a run-of-river scenario where water levels fluctuations in Project impoundments do not exceed 0.25 feet. Unless otherwise approved by the Department, the Applicant shall complete the evaluation by September 30, 2005 and submit a report containing the results of the evaluation to the Department by October 31, 2005. The results of the evaluation shall be used to develop the run-of-river operations plan described in E-7 of this 401 Certification.

E-7. The Applicant shall operate the Project in run-of-river mode, as follows:

a. The Applicant shall develop an operations plan that shall

i. Define, in detail, run-of-river operations, including, but not limited to, provisions for the maintenance of constant water levels in the impoundments and/or constant river flows downstream from Project dams;

ii. Provide compliance monitoring, including reservoir levels, inflow, and outflow at the Garvins Falls, Hooksett, and Amoskeag developments;

iii. Describe the spillway and downstream fish bypass configurations, including design drawings, used to maintain the minimum flows in the bypass reaches described in Condition E-5 of this 401 Certification;

iv. Describe contingency procedures to maintain minimum flows in the bypass reaches or tailraces during periods of failures of the spillway or fish bypass configurations (e.g., obstructions) or emergency shutdowns;

v. Identify spillway and downstream fish passage facility configurations at the Amoskeag dam for distributing water to the east and west channels of the Amoskeag bypass reach;

vi. Describe how the tailrace and bypass channel flows will be impacted when inflows are less than the sum of the permitted minimum tailrace and bypass channel flows described in section E-4 and E-5 of this 401 Certification; and conditions may be imposed or conditions amended by the Department, when authorized by law and after notice and opportunity for hearing.

b. The Applicant shall consult with the Department regarding any proposed modifications to the Project or its operation to determine whether this 401 Certification requires amendment or if a new 401 Certification is required for the Project. Any amendment of this 401 Certification or the issuance of a new 401 Certification, determined appropriate by the Department, shall be required prior to the implementation of any modifications to the Project.

E-10. The conditions of this 401 Water Quality Certification may be amended and additional terms and conditions added as necessary to ensure compliance with NH surface water quality standards, when authorized by law, and after notice and opportunity for hearing.

E-11. The Department may, at any time, request from the Commission the reopening of the license to consider modifications to the license as necessary to ensure compliance with NH surface water quality standards.

F. APPEAL

If you are aggrieved by this decision, you may appeal the decision to the Water Council. Any appeal must be filed within 30 days of the date of this decision, and must conform to the requirements of Env-Wc 200. Inquires regarding appeal procedures should be directed to Michael Sclafani, NHDES Council Appeals Clerk, 29 Hazen Drive, PO Box 95, Concord, NH 03302-0095; telephone 603-271-6072.

If you have questions regarding this Certification, please contact Paul Piszczek at (603) 271-2471.

COPY

Paul M. Currier, P.E.
Administrator, NHDES Watershed Management Bureau

cc: Steve Kartalia, FERC
Jennifer Patterson, NH DOJ
Bill Ingham, NH F&G
Ralph Abele, USEPA
John Warner, USFWS
City of Concord Conservation Commission
Town of Bow Conservation Commission
Town of Hooksett Conservation Commission
City of Manchester Conservation Commission

The State of New Hampshire
Department of Environmental Services

Michael P. Nolin
Commissioner

December 17, 2004

Public Service Company of New Hampshire
Attn: Robert Gunderson, Hydro Manager
PSNH Energy Park
780 North Commercial Street
Manchester, NH 03101

NOTED
DEC 23 2004
GUNDERSEN

Re: Merrimack River Hydroelectric Project – FERC No. 1893

Dear Mr. Gunderson:

Please find enclosed the approved 401 Water Quality Certification (Certification) for the above-referenced project issued by the NH Department of Environmental Services (Department). On December 13, 2004, the Department transmitted a discussion draft 401 Certification to you, your staff, and staff of the NH Fish and Game Department (NH F&G), the U.S. Environmental Protection Agency (USEPA), and the U.S. Fish and Wildlife Service (USFWS) for review and comment. We acknowledge the brevity of the comment period, and are appreciative of the prompt response by your staff and agency staff. All comments received regarding the draft 401 Certification will be addressed in a responsiveness summary, which we will distribute next week.

Should you have any questions regarding the approved 401 Certification, we would be happy to meet with you. The Department looks forward to working with you throughout the new license term to administer the approved 401 Certification.

Sincerely yours,

COPY

Paul M. Currier, Administrator
Watershed Management Bureau

Enclosure: 401 Water Quality Certification

PMC/ppp

cc: Jennifer Patterson, NH DOJ
Bill Ingham, NH F&G
Ralph Abele, USEPA
John Warner, USFWS
City of Concord Conservation Commission
Town of Bow Conservation Commission
Town of Hooksett Conservation Commission
City of Manchester Conservation Commission

P.O. Box 95, 29 Hazen Drive, Concord, New Hampshire 03302-0095
Telephone: (603) 271-3503 • Fax: (603) 271-2867 • TDD Access: Relay NH 1-800-735-2964
DES Web site: **www.des.nh.gov**

State of New Hampshire
Department of Environmental Services
Watershed Management Bureau
29 Hazen Drive, PO Box 95
Concord NH 03302

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ROBERT GUNDERSON
PUBLIC SERVICE OF NH
PO BOX 330
MANCHESTER NH 03103

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DEC 23 2004
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SECOND ADDENDUM TO:

EVALUATION OF INSTREAM MICROHABITAT AVAILABILITY IN THE BYPASS REACH OF THE AMOSKEAG DEVELOPMENT ON THE MERRIMACK RIVER, NEW HAMPSHIRE.

COMPARISON OF FLOW CONTRIBUTIONS TO THE WEST-SIDE DISTRIBUTARIES

Prepared For

Public Service of New Hampshire

Prepared by

Normandeau Associates
Bedford, New Hampshire
and
Stowe, Pennsylvania

October 2004
Revised November 2004

INTRODUCTION

This study is the second addendum to the primary report on microhabitat variation in relation to flow in the bypass reach of the Amoskeag hydroelectric station, operated by Public Service of New Hampshire (PSNH) and located on the Merrimack River in Manchester, New Hampshire (Normandeau 2003). That report focused on results and implications of a Physical Habitat Simulation (PHABSIM) analysis for a variety of evaluation criteria (species and life stages of fish, benthic macroinvertebrates, and physically-defined habitat types) based on empirical data collected at test releases of 50, 150, and 280 cubic feet per second (cfs) into the bypass. Subsequent to the initial report, a first addendum was prepared that provided additional results from a test release of 410 cfs, and coupled those findings with the previous assessment in an integrative fashion (Normandeau 2004). Two elements that emerged from these analyses that have implications for flow and habitat management involved directing flow into specific locations where the utility of flow for improving habitat conditions might be enhanced. One was the idea of strategically modifying channel geometry at key locations in the bypass, and the second was dividing the water supply source between the dam spillway crest and an adjacent fish bypass sluice, in both cases aiming to direct flow into desired locations.

Of particular interest is the pattern and quantity of flow that is routed out of the bypass through the main distributary on the west side of the bypass (Figure 1 in Normandeau 2003). This channel contains predominantly riffle habitat and was originally represented by "transect 5" that crossed the lower section of the flow outlet near its confluence with the Amoskeag tailwater. PHABSIM measurements at a 50 cfs test release from the dam were taken at that location. Relocation further upstream into this channel was forced by high tailwater elevation occurring at the time of the second test release (150 cfs). The new location (transect 10) was retained for subsequent test releases of 280 and 410 cfs (all expressed as totals into the bypass).

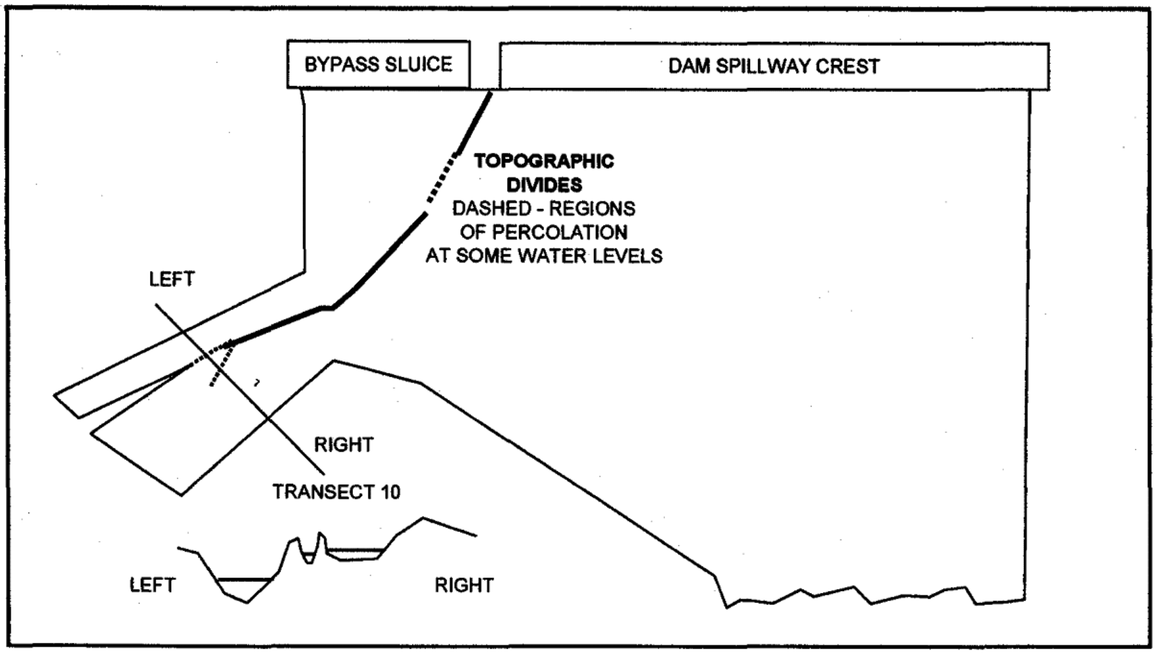
The west-side distributary is potentially fed by two sources of inflow that are largely independent of each other because of topographic divides located near the dam (Figure 1, this addendum). The left portion, which is lower in elevation than the right, is fed primarily by water released through the upstream fish bypass sluice. The right portion is fed primarily by water that flows over the dam spillway, a small fraction of which is directed through a complex of routes that coalesce to create the higher right side of the western distributary. Low points along the main upstream topographic divide allow some percolation of flow from left to right (or vice-versa) depending on water level. Small threads of flow across the middle of transect 10 originate from upstream feeder points along the right side and are believed to remain separate from sluice flow exiting to the left.

The elevated right side of the western distributary crossed by transect 10 contains a higher concentration of gravel and cobble substrate than many other locations in the bypass. This condition likely reflects a lower-energy environment during higher spills that have scoured much of the river bed near the dam, leaving behind physically stable bedrock ledges and large boulders. Some of the surficial bed material found in the western distributary likely consists of the smaller substrate particles washed down from areas closer to the dam. Thus, the value of water flowing through it (compared to other locations) may be increased by passing over substrates typically associated with fluvial species (aquatic organisms dependent on lotic stream conditions). However, substrate and cover data from the original transect 5 and replacement transect 10 revealed considerable patchiness in gravel and cobble substrates within and between the two transects. Also, the specific area is small, representing slightly less than 15 % of the bypass by length of reach and only 7 to 11 % by area, depending on discharge rate. Given these observations, the Agencies requested information on how inflow source and rate interacts with channel geometry to influence flow rates and habitat conditions in the western distributary, primarily as depicted by conditions observed at transect 10.

OBJECTIVES

Based on the foregoing introduction, the objectives of this study were first, to determine the partitioning of discharge across transect 10 related to intervals of discharge from both the bypass sluice and the dam spillway crest. Second, characterization of transect 10 in terms of weighted usable area (WUA) for various evaluation criteria also was requested by the Agencies, and this addendum fulfills that request. In general, such information is a prerequisite for evaluating management options involving flow source manipulation or strategic alteration of instream hydraulic controls.

Figure 1. Conceptual schematic (not to scale) of the routing of flow through the Amoskeag bypass relative to potential sources (bypass sluice or dam crest). Compare to Figure 1 of Normandeau (2003) for an aerial photographic perspective. The area of special interest to the Agencies is the right side of the distributary crossed by transect 10. Flow is toward bottom of the figure.



METHODS

Field Measurements

Relationships between contributing flow source, rate, and conditions observed at transect 10 were assessed using two separate field survey efforts of different timing and duration. The first effort consisted of the measurements taken for PHABSIM analysis under three different release conditions from the Amoskeag spillway crest. These data were collected over a period of several months in 2002-2004. Similar measurements were then taken during a subsequent effort in which flow through transect 10 was provided by opening the fish bypass sluice. This effort occurred on 30 September 2004.

The standard data collected for PHABSIM analysis consists of transect width, water surface elevation (WSEL), interval measurements of bed elevation and water depth across a transect, water velocities at those same increments (usually measured as mid-column, or depth-averaged values), and an indexing of channel substrate and cover characteristics. Elevations were measured with a transit and level rod and referenced to an arbitrary benchmark. Depths were computed by subtracting bed elevations from WSEL, and because WSEL varied among different threads of flow, depth measurements were subtracted from an averaged WSEL and used to adjust the bed elevation profile to conform to a uniform water surface while preserving cross-sectional area. Using such data, the amount of discharge flowing through different parts of transect 10 could be computed at each of the three total test releases studied, which were estimated at 150, 280, and 410 cfs. (Earlier measurements at a 50-cfs test release took place at transect 5). Discharges passing through the left and right sides of a central topographic divide along transect 10 were computed by summing the products of cell width, depth, and velocity across each side of the divide.

During the PHABSIM study, the fish bypass sluice remained closed and any flow draining out the left side of transect 10 resulted from limited percolation across or through upstream topographic divides that separate the left and right sides of the western distributary. For comparison, cross-sectional depth and velocity data were collected at transect 10 on September 30, 2004, at three different flows resulting from bypass sluice gate openings of 1, 1.5, and 2 ft, while no flow (other than leakage) came down over the main dam crest.

Data Analysis

The primary data analysis consisted of computing total discharge through the western distributary under each release condition, and estimating the subtotal flowing through the left and right sides of transect 10. Depth and velocity distributions were determined by graphical analysis and presented in addition to the partial and total discharge estimates and WUA calculations. Translation of physical characteristics associated with spillway releases to the WUA habitat index was reported earlier (Normandeau 2003, 2004). For this study, WUA calculations were performed using data restricted to transect 10 measured at the three bypass sluice gate openings or three of the four test releases over the spillway crest. Data from the 50-cfs release were omitted because they were collected at transect 5.

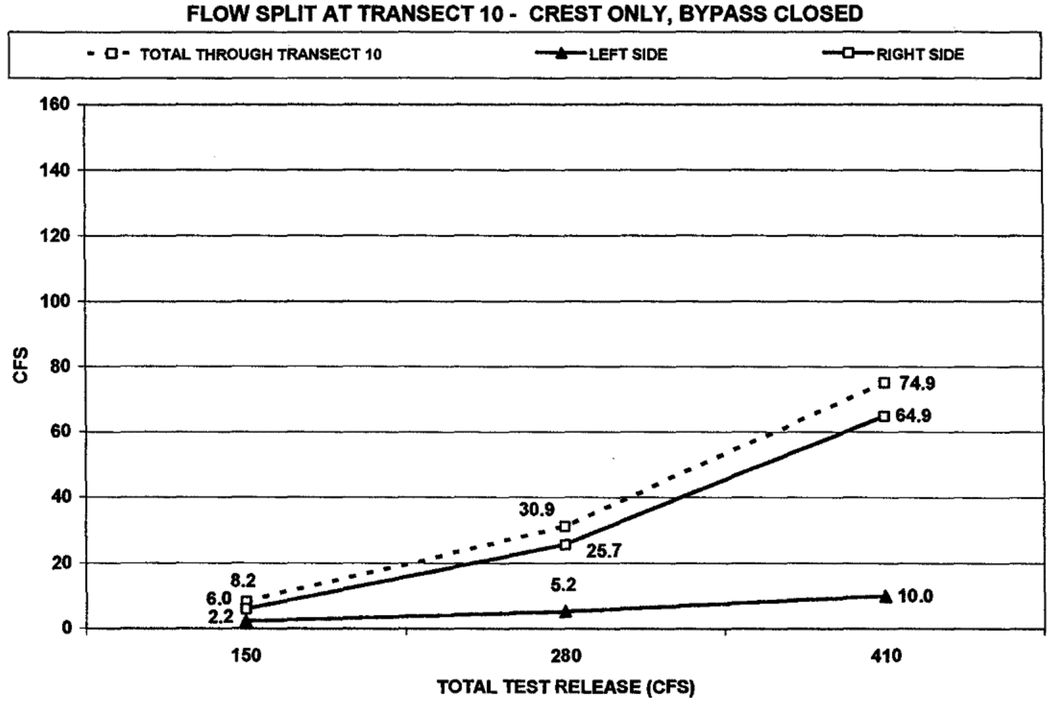
RESULTS

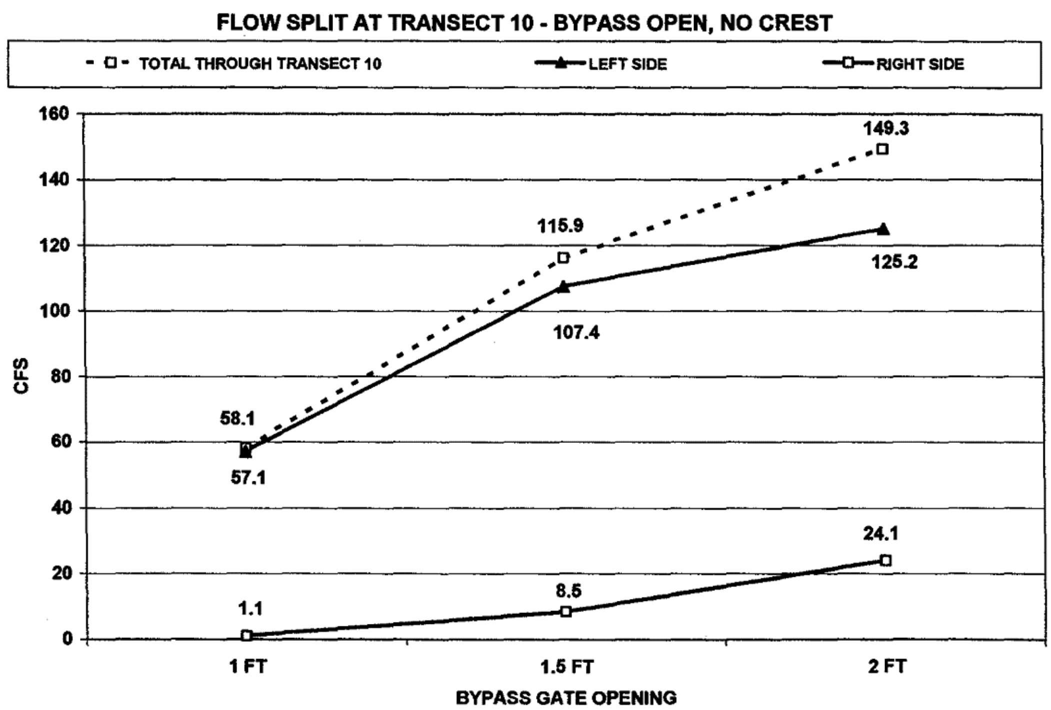
Variation in Discharge across Transect 10

Changes in discharge through the western distributary observed under three test release conditions over the Amoskeag bypass spillway crest are shown in the top section of Figure 2. These flows stem from spillover from upstream pools near the base of the spillway crest, and amounted to approximately 5, 11, and 18 percent of the total release for the 150, 280, and 410 cfs tests, respectively. Calculated rates differed slightly between EXCEL and RHABSIM computer programs but the differences were within the range of field measurement uncertainty. Most of the flow exiting via the western distributary during these tests is confined to the higher right side of transect 10, but a small amount percolates across and exits via the lower left-side channel.

Changes in discharge through the western distributary observed during three different gate openings are shown in the bottom section of Figure 2. The total through transect 10 represents the overall rate of release, as no water percolated over into the main eastern exit of the bypass (Mike Jeanneau, Normandeau, personal communication). From these graphs, it is clear that upstream topography and release source interact to control the distribution of flow through the higher and lower subchannels of transect 10. Note that a 2-ft gate opening provides almost the same amount of flow to the high right side of transect 10 as a 280 cfs spill over the dam crest, but only uses about 116 cfs of discharge and maintains over 100 cfs down the lower left side channel. Also, a 1 ft gate opening provides almost the same total flow through transect 10 as a 410 cfs release over the spillway, although as shown in Figure 2, the proportions passed by the left and right sides differ markedly.

Figure 2. Top: changes in discharge through the western distributary observed under three test release conditions over the Amoskeag bypass spillway crest. Bottom: same, but with flow source via three different height openings on the fish bypass sluice gate.



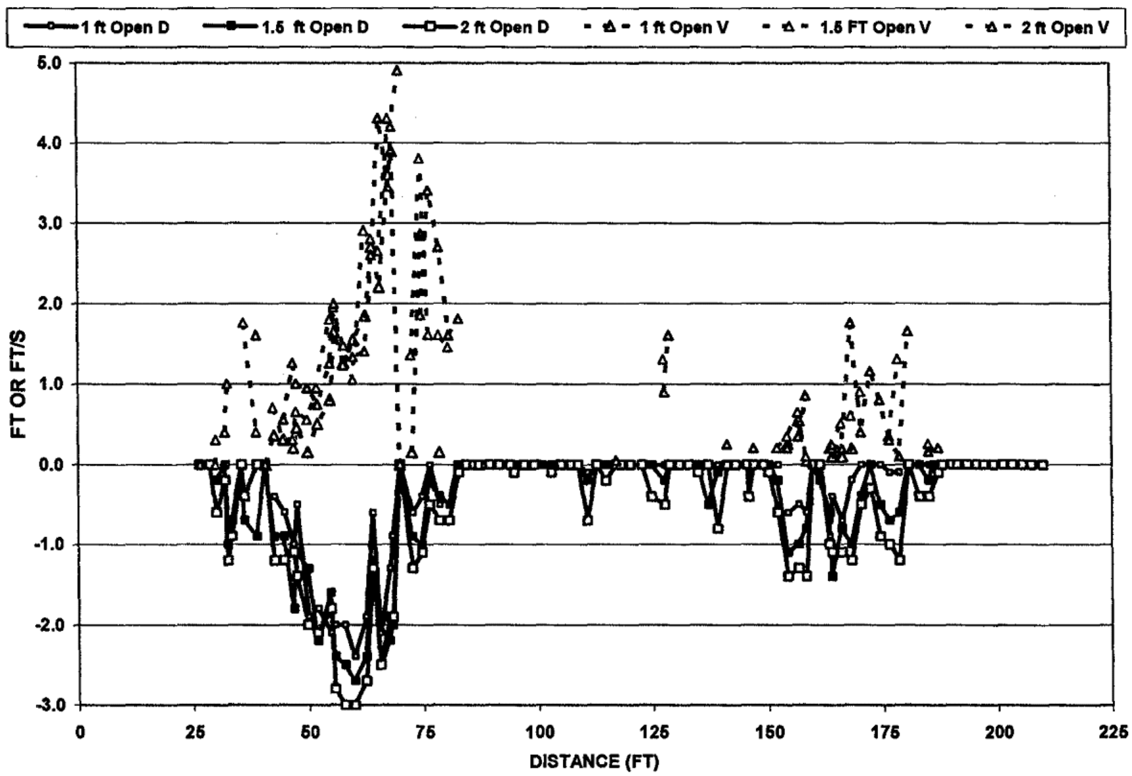


Depth and Velocity Distributions

Depth and velocity distributions across transect 10 provided by flows from the three gate openings are shown in Figure 3. Variation in depth across the range of gate openings was about 0.75 ft in the lower left side and closer to 1 ft in the main thread of the right side. Velocity exceeded 2.0 ft/s in a few measurement cells within the left side at all gate openings and peaked above 4.0 ft/s in all cases. Velocities remained below 2.0 ft/s in all cells within the right side for all three gate openings.

To better visualize conditions measured in the field, a selection of photographs under a variety of conditions is presented in the Appendix.

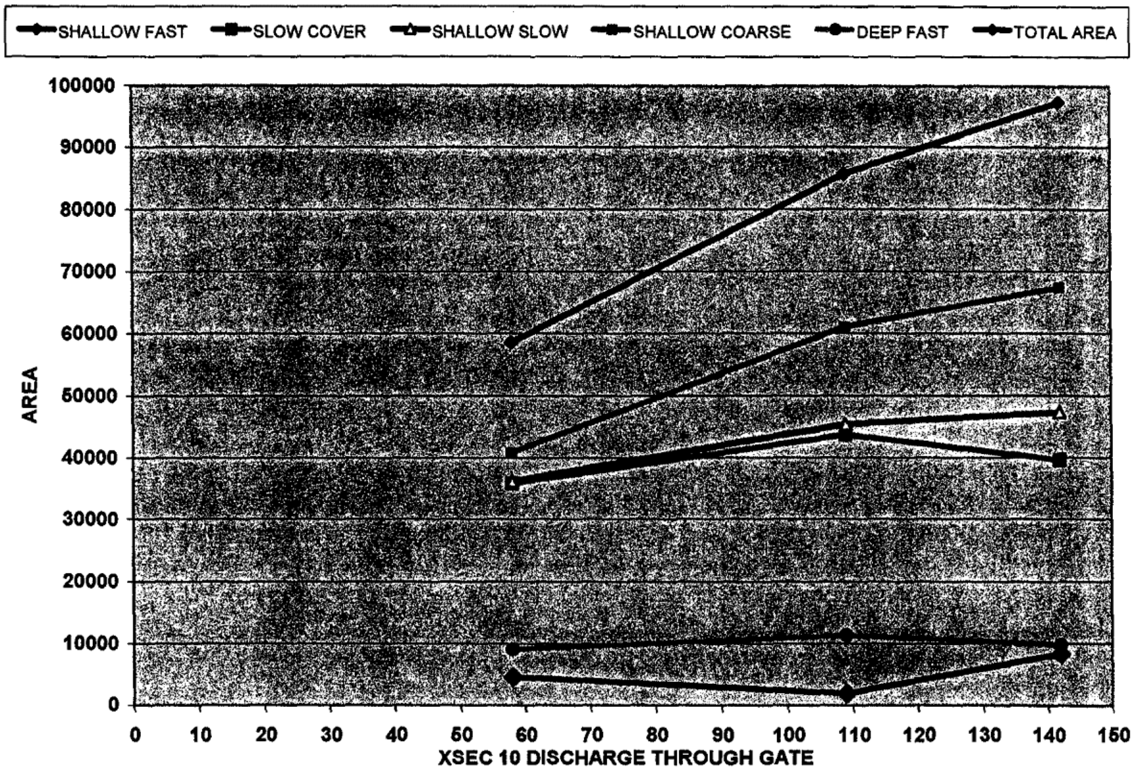
Figure 3. Depths (ft) and velocities (ft/s) observed at transect 10 across the western distributary of the Amoskeag bypass at three different gate openings at the fish bypass sluice.



Sources of Variation in WUA

Figure 4 gives a series of charts showing WUA (units standardized to square feet per 1,000 ft of channel) in relation to flow at transect 10 provided by the two alternative sources of inflow (sluice gate or spillway crest). Note that there are always some differences between the nearly identical flows through transect 10 provided by either a 1 ft gate opening (corresponding to a release of 58 cfs) or a 410 cfs spillway release; these differences reflect differences in flow distribution between the left and right sides of transect 10.

Figure 4. Flow versus WUA at transect 10 for three flows provided by gate openings of 1, 1.5, and 2 ft (upper panels) and flows over the spillway crest of 150, 280, and 410 cfs (lower panels).



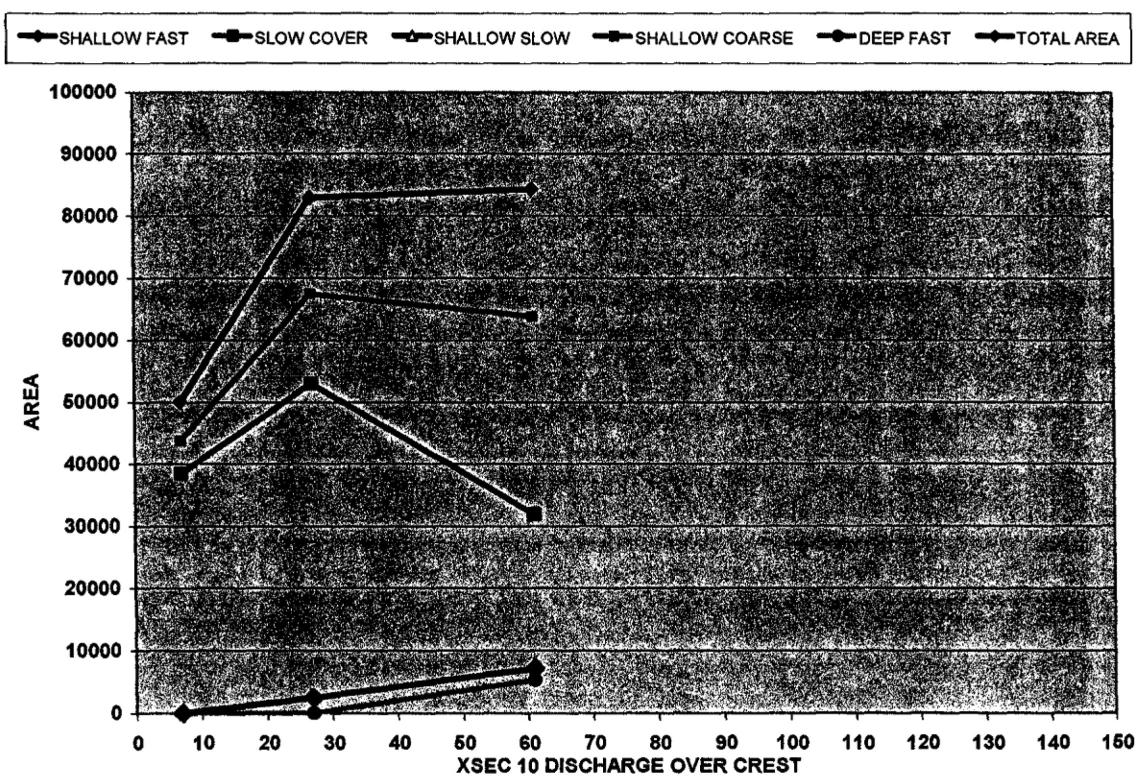


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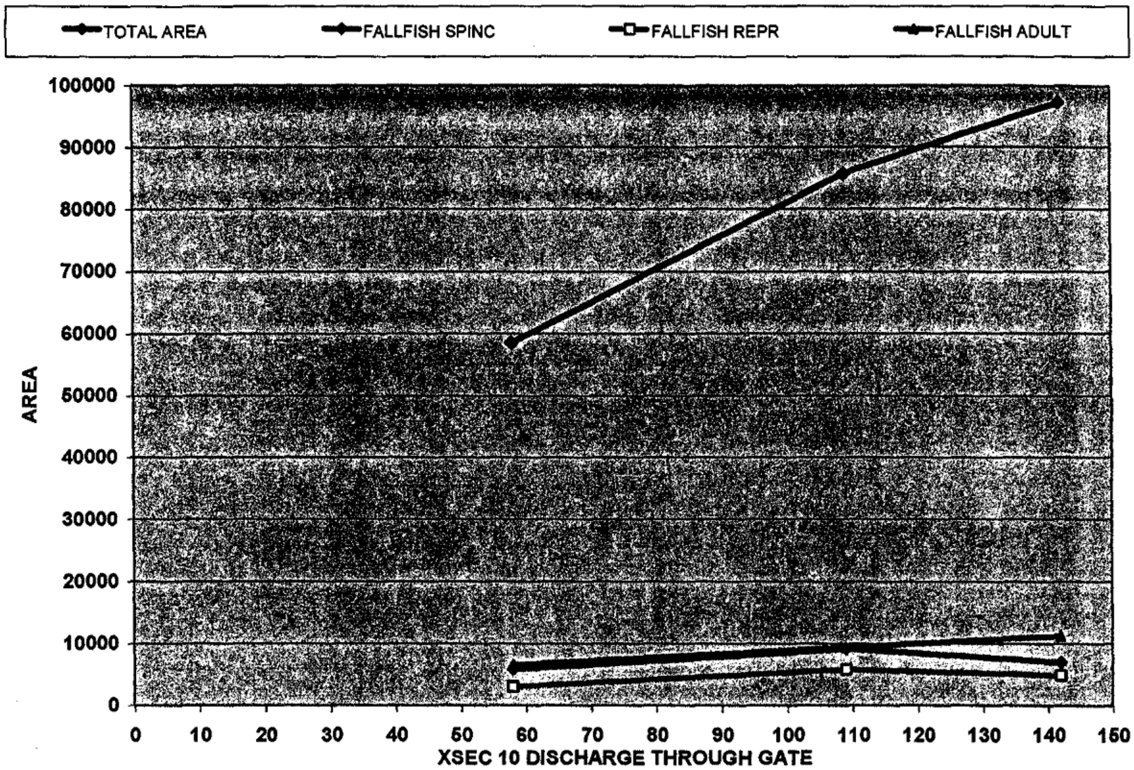
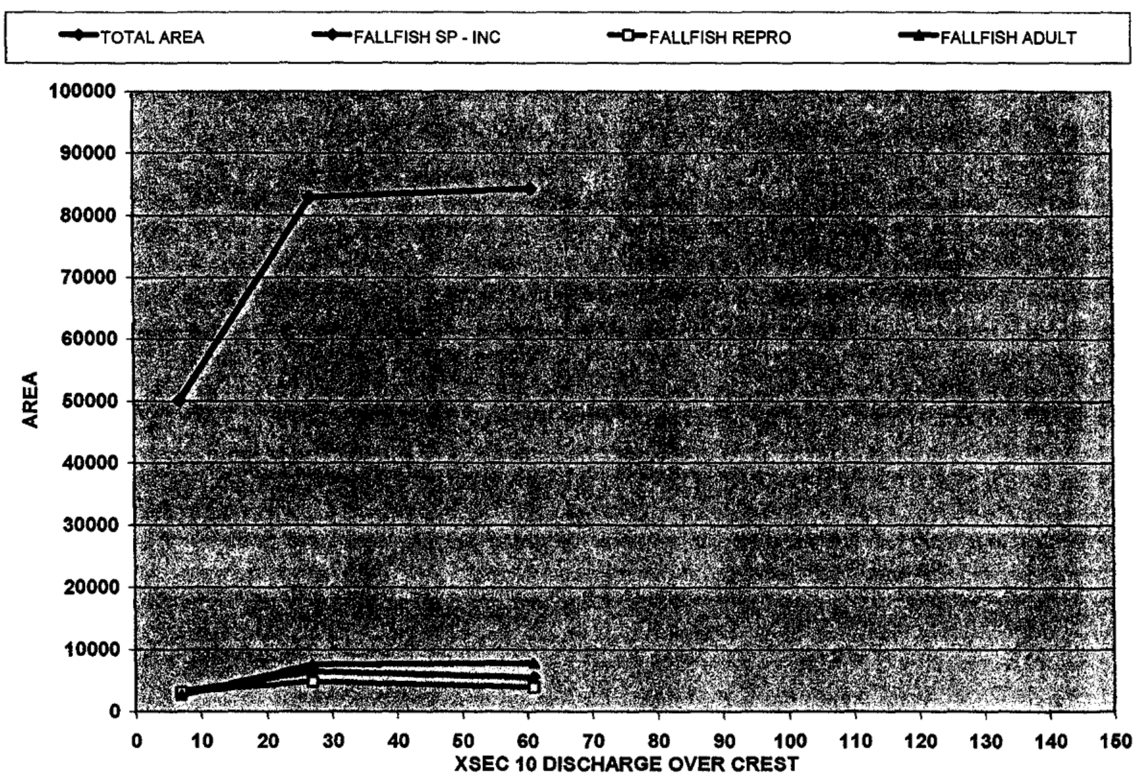
Figure 4. Continued.





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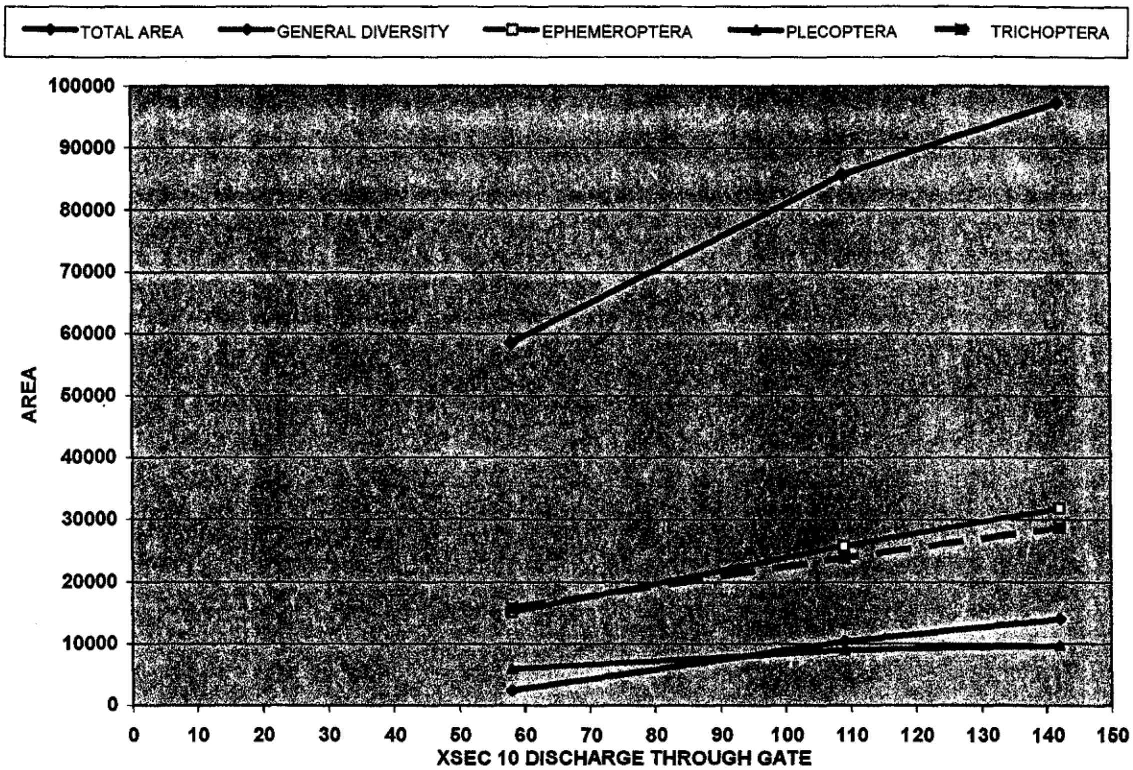


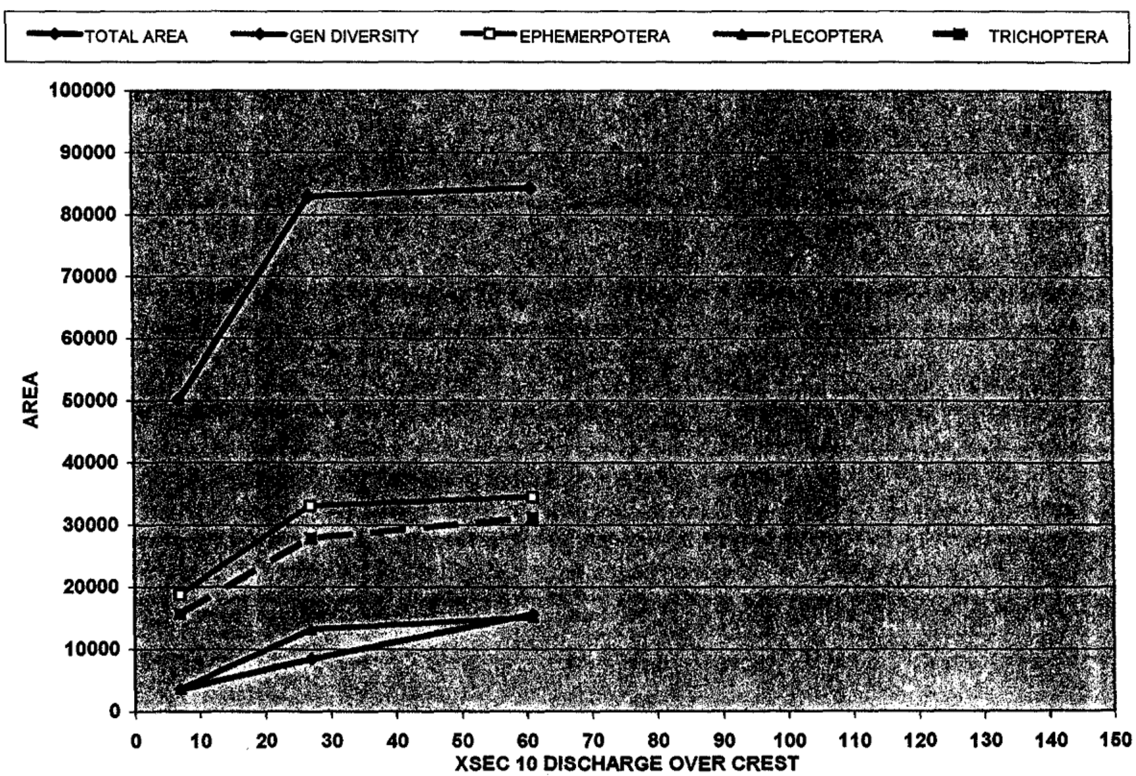
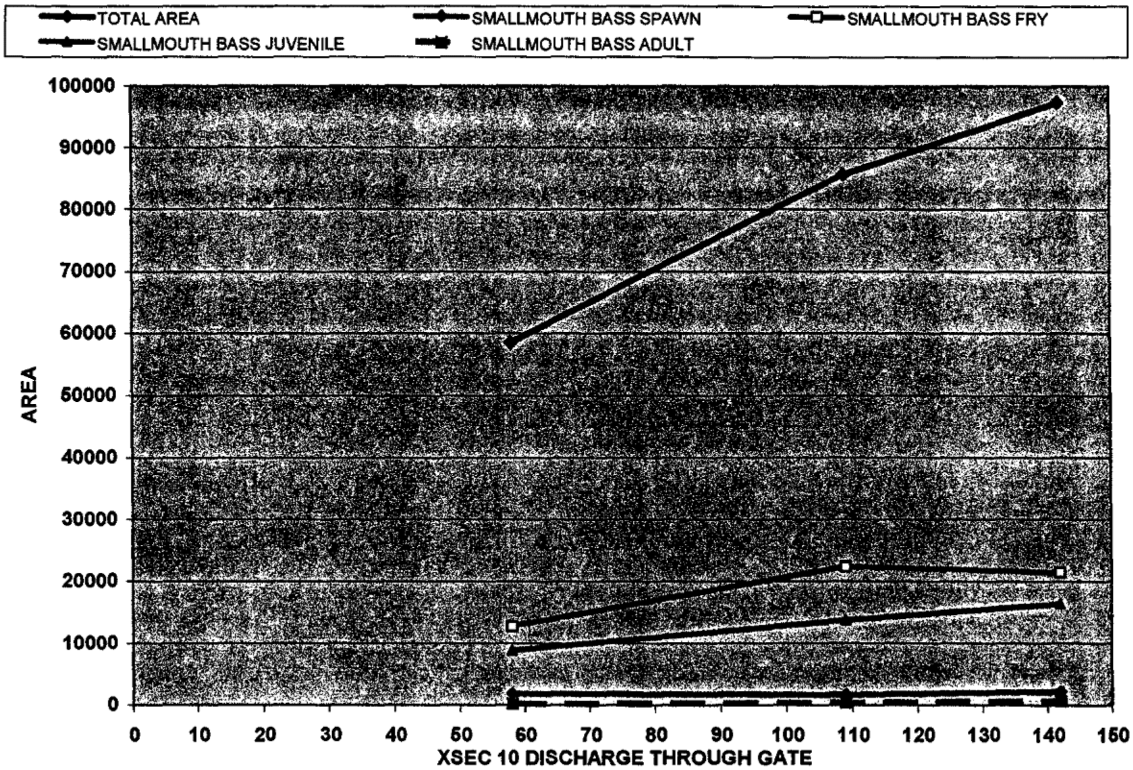
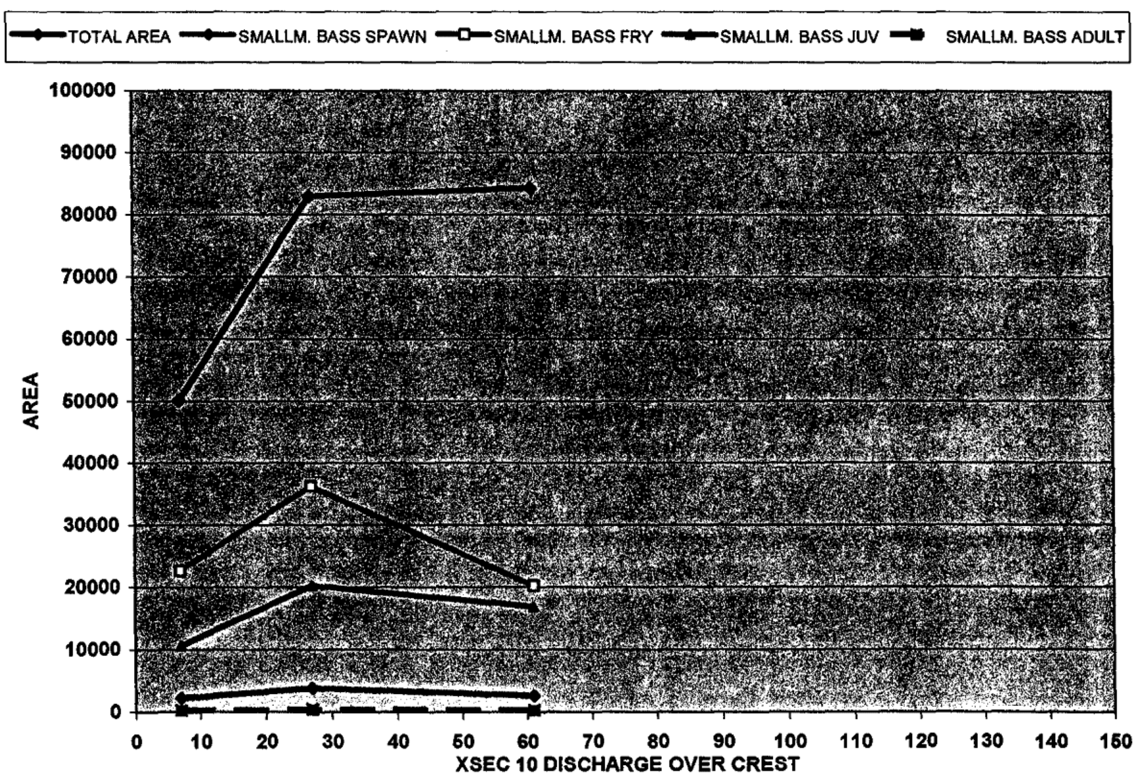


Figure 4. Continued.





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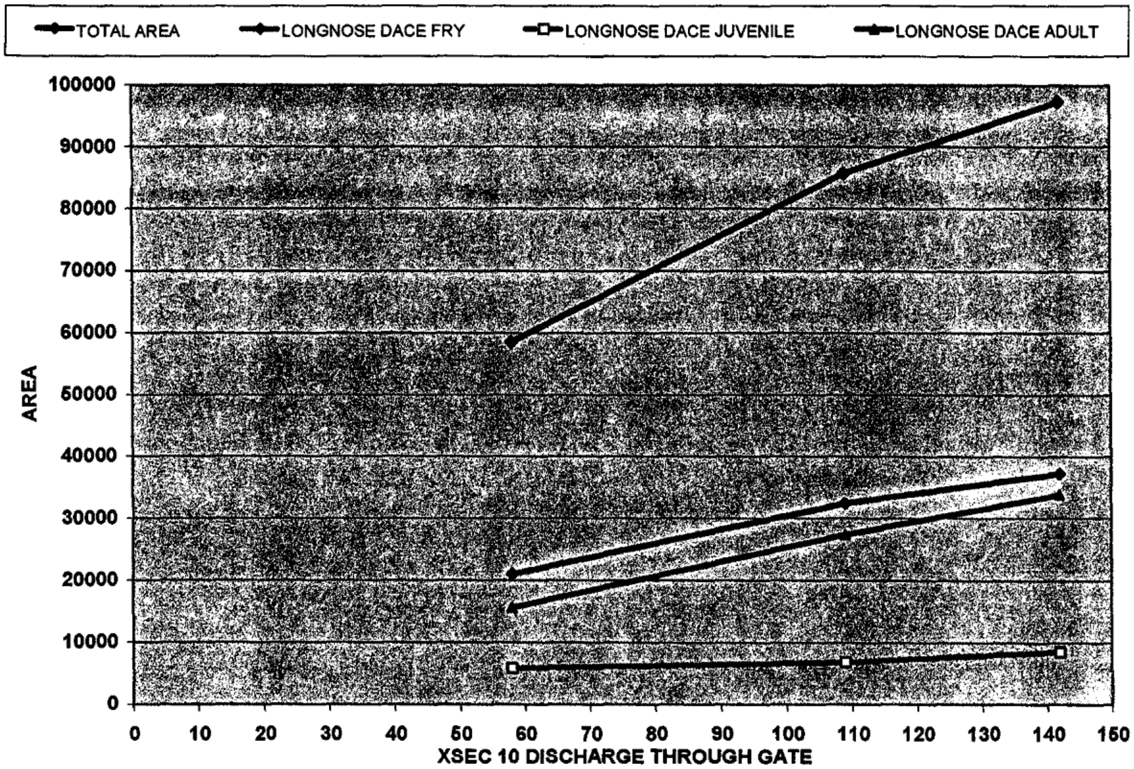


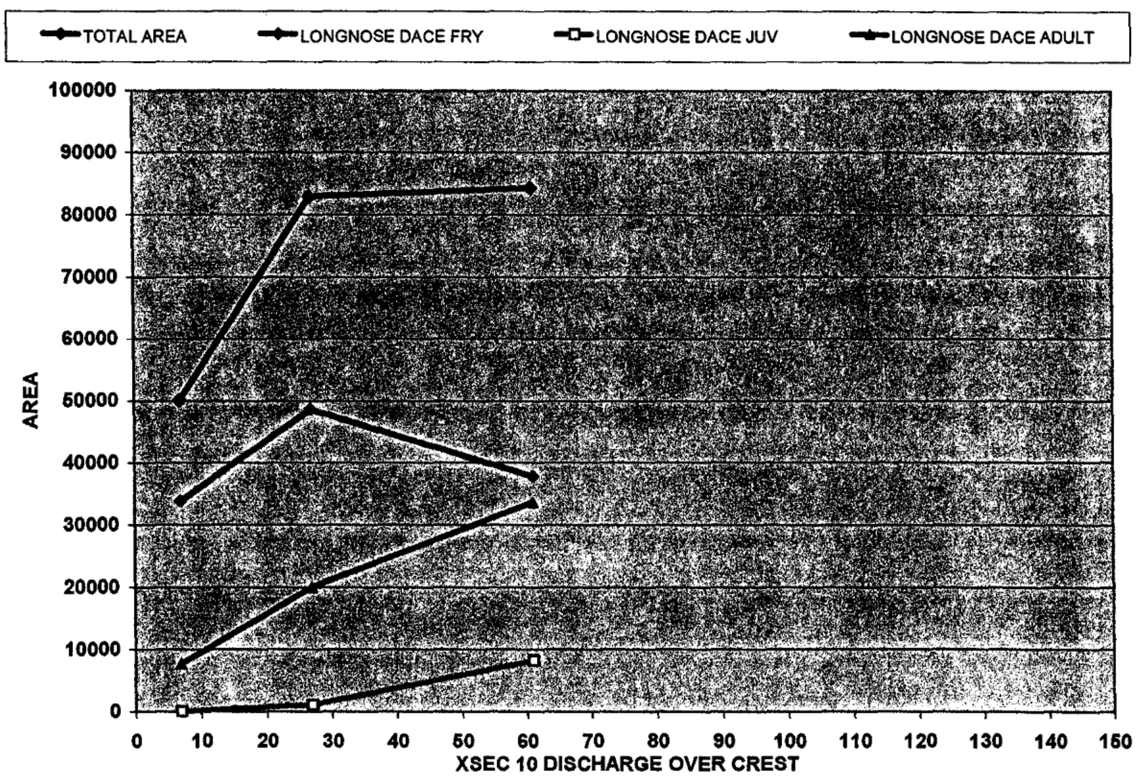
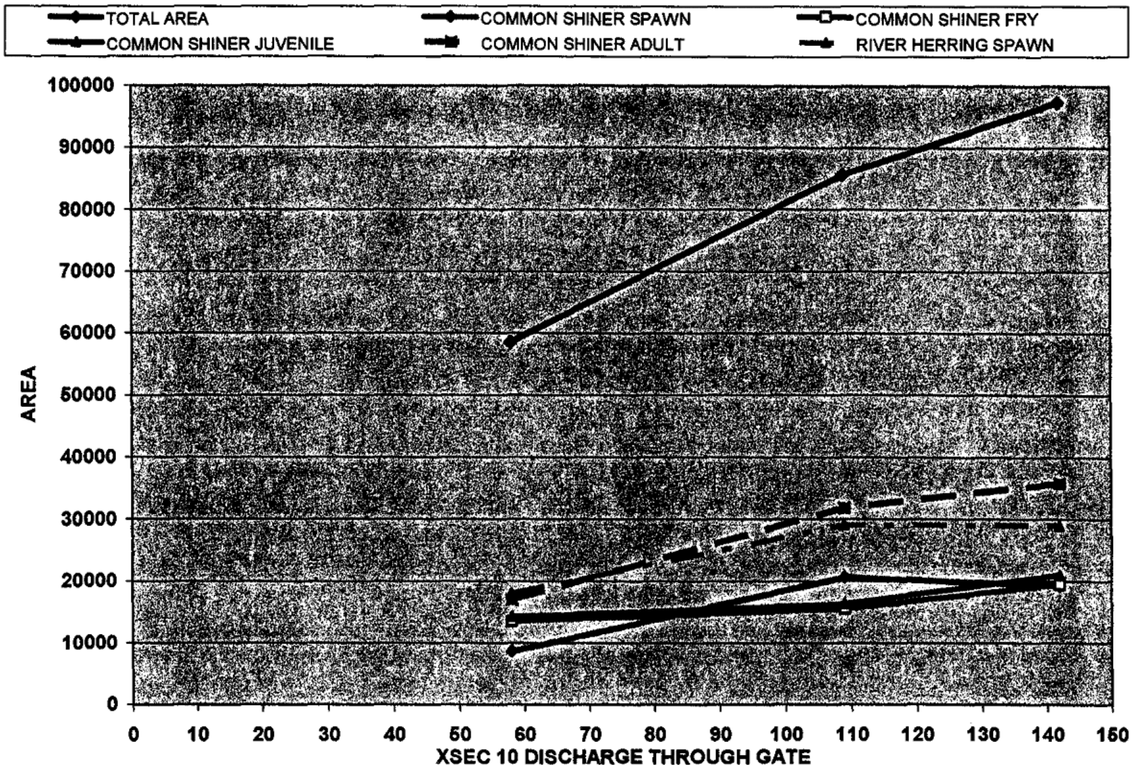
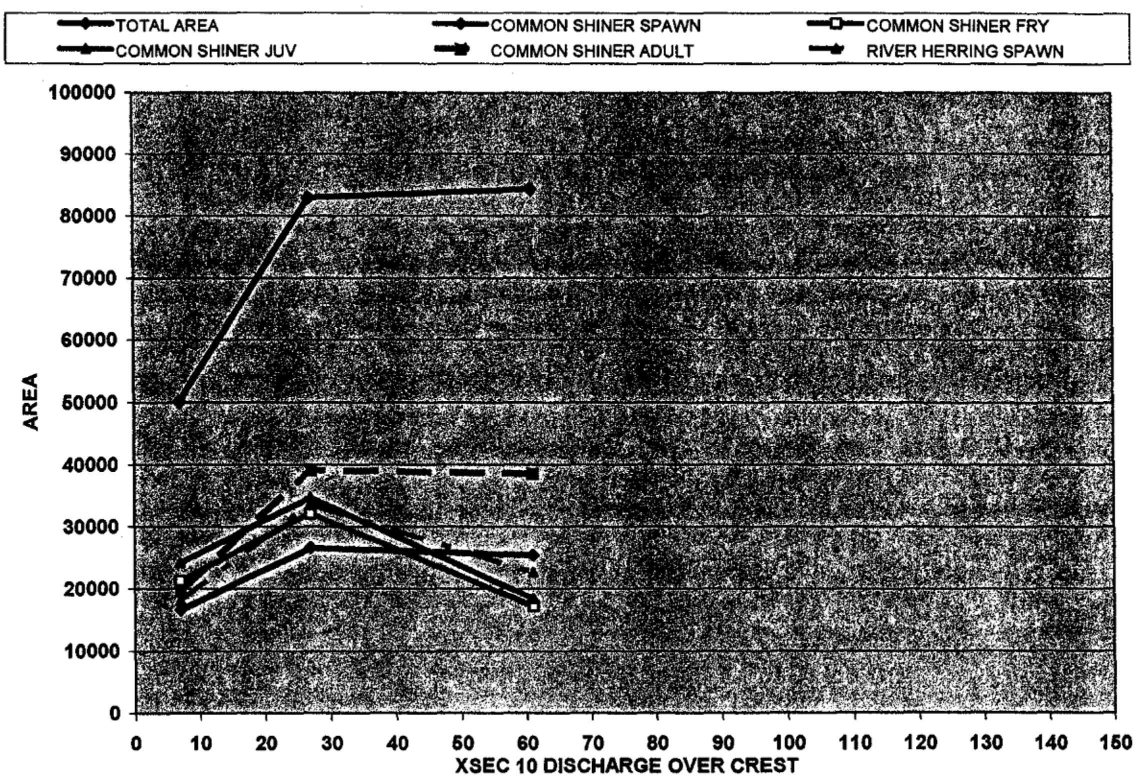


Figure 4. Continued.





DISCUSSION

The foregoing analysis demonstrates that the source of flow into the Amoskeag bypass is an effective control for manipulating the amount of discharge through the two subchannels of the western distributary. In terms of fractional water use, the bypass sluice is more efficient than the spillway crest, in that a total release of 150 cfs provides as much discharge down the right side as a release of 280 cfs over the dam, and it provides fifteen times as much flow down the left side as a 410 cfs release from the dam. However, habitat conditions similar to those on the right side of transect 10 also occur at the multiple exits of the primary eastern outlet of the bypass, so for a given *total* release rate, provision of some through the bypass sluice would reduce the flow exiting the east side of the main bypass. Unfortunately, the result of these differences on fish habitat characteristics as indicated by empirical WUA values (Normandeau 2003, 2004) can only be estimated roughly because of the inability to simulate unobserved physical conditions. Also, provision of flow via both the sluice and the spillway would likely result in conditions down the right side of transect 10 that differ from those that result from either source alone, because both avenues contribute flow to the western distributary from different directions.

Ultimately, flow in the western distributary is controlled by the elevation and configuration of the outlets to upstream pools that intercept flow from either the bypass or the spillway before it is transferred downstream. This study shows that flow source manipulation, and potentially the rearrangement of topography at key locations, are additional controls on flow and habitat conditions in the bypass that could be considered when devising a management regime.

REFERENCES

Normandeau Associates. 2003. Evaluation of instream microhabitat availability in the bypass reach of the Amoskeag Development on the Merrimack River, New Hampshire. Prepared for Public Service of New Hampshire.

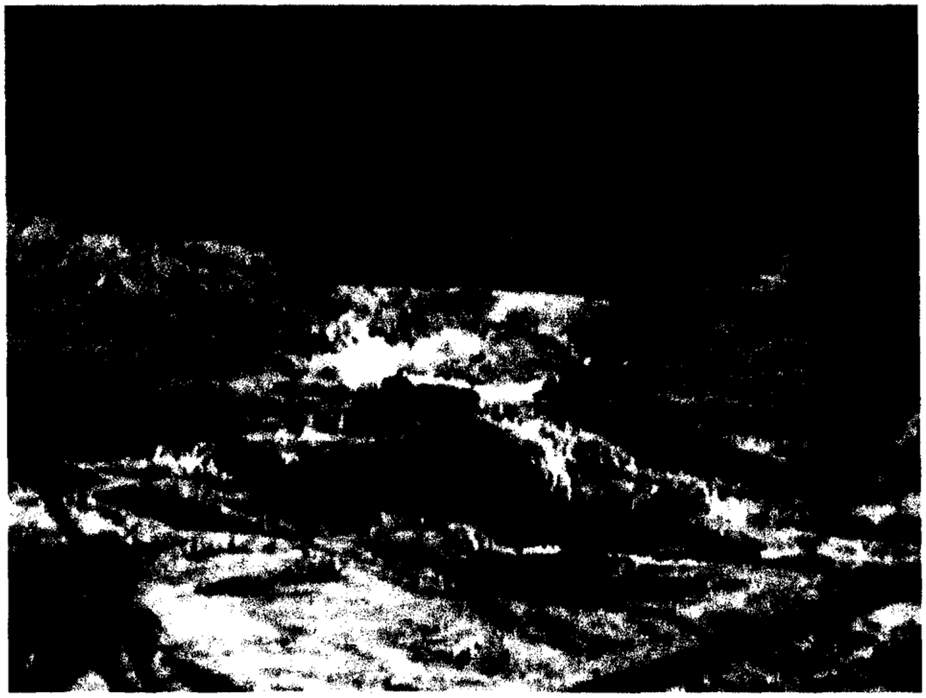
Normandeau Associates. 2004. First Addendum to: evaluation of instream microhabitat availability in the bypass reach of the Amoskeag development on the Merrimack River, New Hampshire. Further analysis including evaluation of conditions at 410 cfs. Prepared for Public Service of New Hampshire.

APPENDIX
Selected Photographs of Site Conditions

Above: exit of the right side of western distributary (below transect 10) at total release of 150 cfs over the Amoskeag spillway crest. Local flow was estimated at 6.0 cfs here and 2.2 cfs in left side below the bypass sluice (Below).

Above: left side looking upstream from transect 10 at 280 cfs total release over the dam crest. Local flow estimated at 5.2 cfs. 25.7 cfs.

Below: right side looking upstream from transect 10 at 280 cfs release; local flow estimated at 25.7 cfs through right side of transect 10.

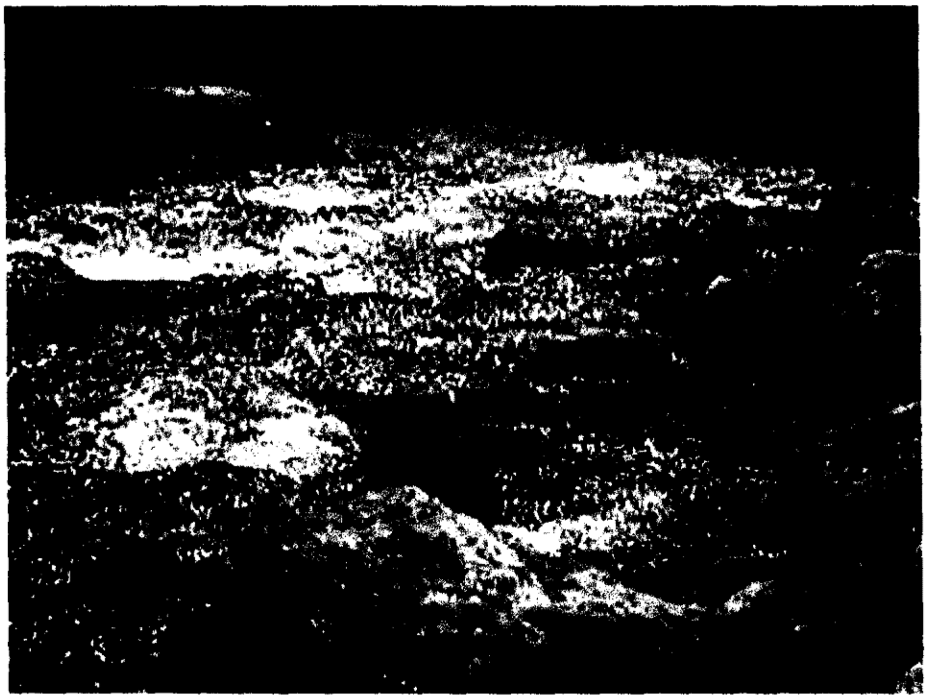


Above: right side looking upstream above transect 10 at 410 cfs test release over dam crest. Below: right side looking downstream below transect 10 at 410 cfs. Local flow through this distributary was estimated at about 65 cfs at transect 10. About 10 cfs percolates through to the left side as it flows through this route.

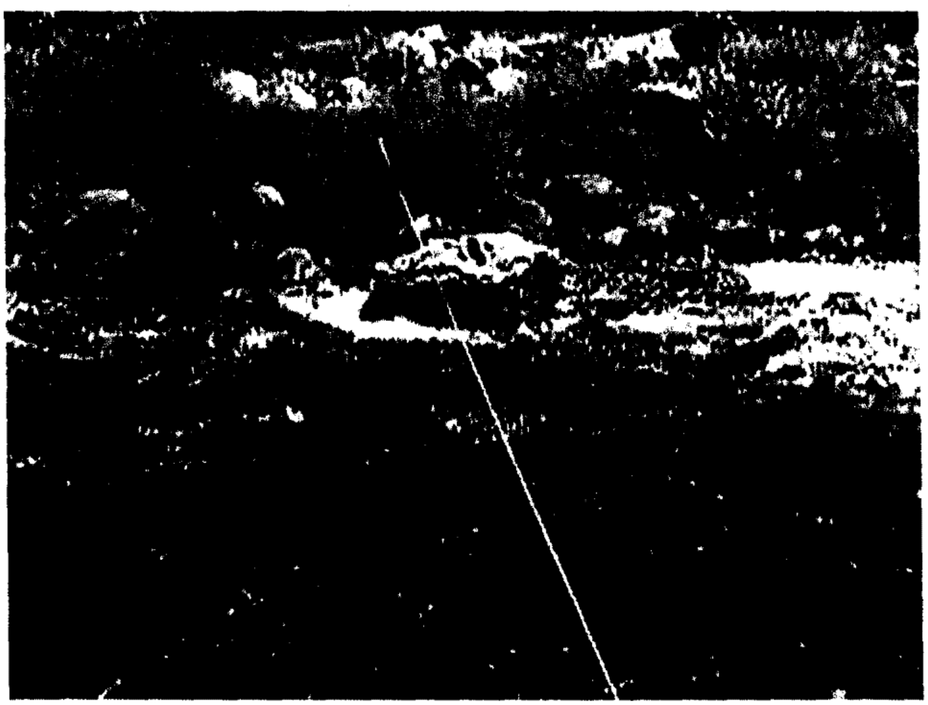
Above: Left side of transect 10 looking upstream toward the bypass sluice at a 1 ft gate opening.
Below: Same, looking downstream.

Above: right side of transect 10 looking upstream at an opening of 1 ft on the bypass sluice gate.

No downstream view available.

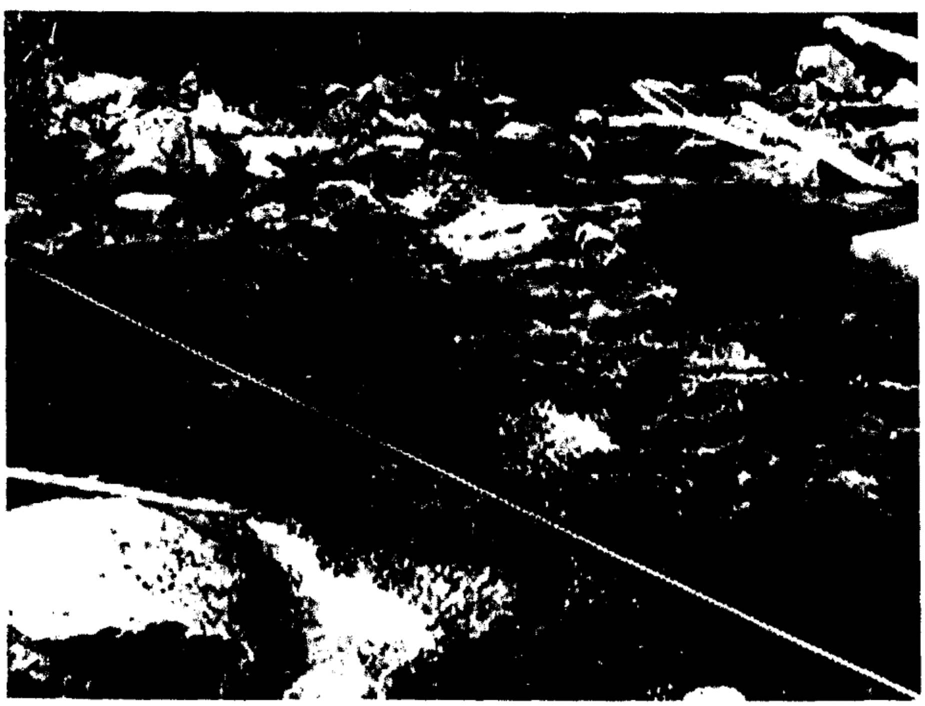


Above: left side of transect 10 below fish bypass sluice at a gate opening of 1.5 ft.
Below: same location, looking across channel. Local discharge is about 107 cfs.



Above: right side of transect 10 looking downstream at a gate opening of 1.5 ft.
Below: from same location, looking upstream. Local discharge is about 8 cfs.

Above: left side of transect 10 below fish bypass sluice, looking across channel at a gate opening of 2 ft.
Below: same condition, looking at an angle upstream. Local discharge is about 125 cfs.



Above: right side of transect 10 looking upstream, at a gate opening of 2 ft at the bypass sluice.
Below: right side, looking downstream from above transect 10. Local discharge is about 24 cfs.

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EVALUATION OF INSTREAM MICROHABITAT AVAILABILITY IN THE BYPASS REACH OF THE AMOSKEAG DEVELOPMENT ON THE MERRIMACK RIVER, NEW HAMPSHIRE

ADDENDUM:

FURTHER ANALYSIS INCLUDING EVALUATION OF CONDITIONS AT 410 CFS

Merrimack River Hydroelectric Project
FERC Project No. 1893

Prepared by:

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July 2004

INTRODUCTION

This study is an addendum to the primary report on microhabitat variation in relation to flow in the bypass reach of the Amoskeag hydroelectric station, located on the Merrimack River in New Hampshire (Normandeau 2003). The investigation was conducted on behalf of Public Service of New Hampshire (PSNH) by Normandeau Associates. The original study was based on empirical habitat modeling using field methods and computer software known as the Riverine Habitat Simulation System (RHABSIM, TRPA 2001). Following completion of the primary evaluation based on test flows of 50, 150, and 280 cfs, the stakeholder natural resource management agencies requested that PSNH evaluate a fourth, higher test flow. Part of the impetus for the request was the observation that weighted usable area (WUA) for some target species and life stages was greater at 280 cfs than at 150 cfs. PSNH consulted with Normandeau and the agencies and determined that a release in the range of 400 to 450 cfs would likely be sufficient to create a downturn or plateau in WUA for many of these cases because optimum velocity ranges would be exceeded within more of the channel at such flow levels.

Information about the conduct and results of the overall study of which this addendum is a part is presented in the initial study report by Normandeau (2003). Aspects of methodology presented here are restricted to elements of the study that are specific to the measurement of data at the fourth test flow, and their incorporation into the overall assessment of habitat conditions in the bypass in relation to flow.

METHODS

Field Measurements

The configuration of notches on the flashboards across the Amoskeag weir at the head of the bypass needed to provide a flow in the target range was estimated and implemented by PSNH. Normandeau field personnel rated the ensuing test flow, and following a minor adjustment, field measurements were conducted at the nine transects surveyed previously (transect 10 continued to replace transect 5). Head and tail pin locations were confirmed, and the field crew then measured wetted top width along with depth and mid-column stream velocity at previously defined intervals along each transect. Water surface elevations (WSLs) benchmarked to arbitrary headpin elevations were measured at several points along each transect and used in RHABSIM to define a model water surface from which observed depths were subtracted to estimate the vertical coordinates of the stream bed. Descriptions of field equipment and application procedures were reviewed in the primary report.

The field crew visually compared gross channel morphology and cover/substrate characteristics to photographs and videos of conditions at earlier test flows and determined that any changes were minor and did not warrant re-evaluation. They estimated total discharge by combining discharges from transects 10 and 7, which together carried essentially all the visible surface flow coming from upstream and had reasonably good characteristics for estimating flow rate. Conditions at the fourth test flow were also photographed and video-taped to extend the visual archive available for review.

Data Analysis

Field data were checked for completeness and accuracy and used to update analysis spreadsheets and stream habitat models in RHABSIM. Apparent discharge estimates were generated for each transect automatically by processing the field data through the HYDSIM module in RHABSIM.

As explained further in the results, adjustments were made to the recorded velocities at transects 1 and 2 for the 410 cfs, and at transect 2 for the 280 cfs flow. The latter adjustment required the 280-cfs data set to be re-processed, which changed WUA values for that location at that flow, but did not greatly affect relationships between flow and WUA for the bypass considered as a whole.

Field crews reported that substrate and cover characteristics along transects had remained stable at a mesohabitat scale, thus the coding for those variables in RHABSIM remained constant at all four flow releases. Because cross-sectional geometry differs slightly in the data set for each flow in order to preserve the empirical depth at each measurement vertical, graphs of the cross-sections were compared visually to ensure that local channel dimensions had not changed appreciably. Changes in habitat conditions were investigated by inspecting hydraulic information generated by RHABSIM, and summarizing the main patterns of variation therein with principal components analysis (PCA using the CANOCO 4.0 software package, Ter Braak and Smilauer 1998).

The processed field data were interfaced with the same habitat suitability criteria (HSC) used in the main report, to generate relationships between flow and WUA for individual transects and for the entire bypass reach. Briefly, the evaluation cases included HSC for three orders of benthic macroinvertebrates and general macroinvertebrate diversity, a set of constraints that define five different, but potentially overlapping "key habitat types" and a mutually exclusive system of 36 "generalized" microhabitat types. Multiple life stages (typically spawning and/or fry, juvenile, and adult) of smallmouth bass, fallfish, common shiner, longnose dace, and spawning criteria for river herring were evaluated. For smallmouth bass, two different sets of HSC were used to explore effects of differences in perceptions of suitability. The HSC were category I (literature based) criteria and were reviewed by stakeholders prior to implementation. Relevant literature was cited in the primary report. From a systems analysis perspective, the key-and-generalized habitat criteria are simply alternative filters to biological HSC through which to view and understand physical habitat change caused by variation in flow.

Studies that employ many target species and life stages usually reveal that flow levels and regime characteristics that increase habitat for some species cause habitat to decrease for others. Factoring in these plusses and minuses in a water management decision framework on a case-by-case basis is problematic. Methods for describing relationships at the higher level of organization represented by the entire set of evaluation criteria could prove useful in balancing competing demands on water resources. Following this reasoning, the WUA metrics generated by RHABSIM models for each evaluation case (which are computed on a transect-by-transect basis for each test flow) were treated as a response variable amenable to multivariate analysis. Briefly, ordination methods applicable to two underlying models of response to environmental change (linear and unimodal) were used to examine relationships within the entire dataset. Correlation-based PCA of a matrix of WUA values for target biota by test flow-transect combination was one method employed that assumes WUA responds linearly to changes in test flow. Detrended correspondence analysis (DCA) assumes a unimodal response where the peak value occurs between the extremes of the underlying gradients represented in the dataset. Canonical correspondence analysis (CCA) also assumes a unimodal response but constructs ordination axes to be linear combinations of supplied environmental variables. Here, CCA was used to relate variation in the WUA matrix to selected hydraulic characteristics generated by RHABSIM. It should be noted that unimodal and linear models often produce qualitatively similar descriptions of dataset variation in cases where unimodal responses are not strongly peaked, as occurred in this case. These ordination analyses were performed using the CANOCO version 4.0 program cited previously. Results were presented as ordination diagrams that were coded to represent relationships between test flows, transects, and evaluation cases. Similar analyses were performed on a matrix of area values for key and generalized habitat types.

RESULTS WITH DISCUSSION

Flow Conditions at Transects

The braided configuration of flow through the Amoskeag bypass creates a complex mosaic of habitat patches and cross-sectional flow characteristics. Complex variation in topography results in each major thread carrying a different fraction of total bypass flow at each test release (Table 1). Of the two major exits out of the bypass, one flows along the eastern shore and the other branches off toward the west (see Figure 1 of the primary report). The eastern thread then splits into several smaller sub-channels before joining the adjacent Amoskeag tailwater. Along with transect 7 to the east, the total bypass release was intercepted by adding the flow from those that crossed the western exit (either transect 5 or transect 10). Recall that transect 10 replaced transect 5 at the 150 cfs and higher releases. Rounding the computed partial discharges at transects 7 and 10 to the nearest 10 cfs gave a total bypass flow estimate of 410 cfs, which is considered the nominal flow value for the fourth test flow used in this study. Because transects vary in their suitability for measuring discharge, other combinations that appear to intercept all the flow (or all the flow down the east side, for example) do not sum to the same values, but do give estimates that were considered reasonable given typical bounds on the uncertainty of measuring discharge in coarse-bedded streams with irregular topography.

The fraction of total discharge carried by each sub-channel in the bypass is a function of the controlling topography at the upstream end of each drainage feature. While these fractions are expected to vary from one release condition to the next, there should be a monotonic increase in partial discharge with increasing total bypass flow within each sub-channel assuming stable channel geometry. Partial discharge estimates for transects 1 and 2 at 410 cfs based on empirical velocity measurements did not meet this expectation. Furthermore, the discrepancies were greater than what would be caused by irregular velocity fields across transects. The field crew indicated there were no noticeable changes in topography and that flows at all locations were definitely higher than they had been at the previous test release (280 cfs). Barring a change in channel geometry, a velocity-meter reading error is a reasonable explanation for the discrepancy.

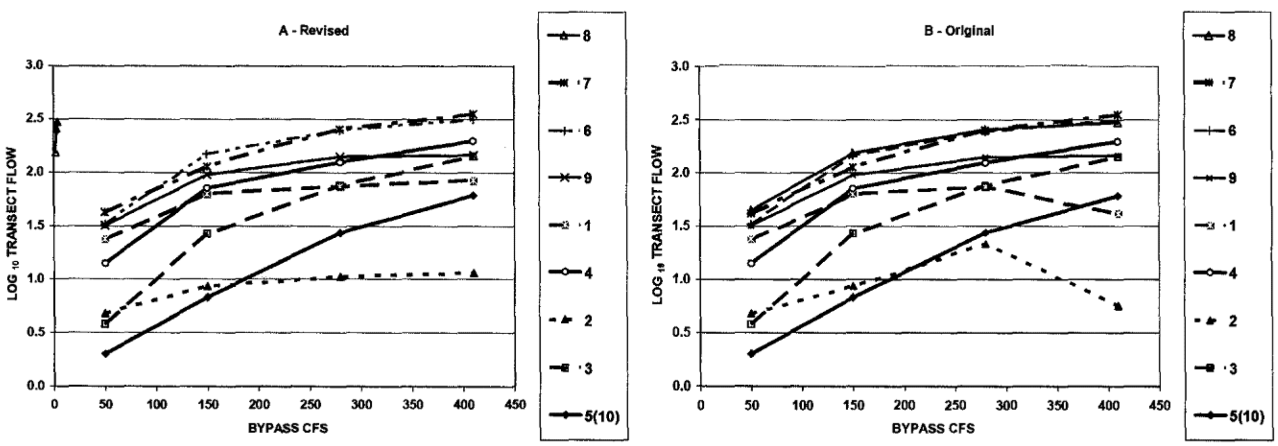
The analog-version of the Marsh-McBirney electromagnetic flow meter, which was used on these transects, has three different measuring ranges that increase by a factor of two at each level going up-scale. If a reading is made from one scale while the selector switch is set to a different scale, the resulting velocity reading could be one-half or twice the correct value. Thus, doubling the velocities recorded in the field for transects 1 and 2 at 410 cfs approximately doubled the apparent partial discharges, which for transect 1 gave the desired monotonic increase between partial discharge and total bypass flow. However, the partial discharge for transect 2 was either not high enough at 410 cfs, or too high at 280 cfs, to produce a monotonic increase. But if the velocities from transect 2 at 280 cfs were halved, and combined with the revised data from 410 cfs, the expected relationship emerged. Although the change between 280 and 410 cfs was quite small at transect 2, it was in the expected direction. The specifics of the influent hydraulic control, coupled with normal measurement uncertainty (i.e., discharge measurements often vary by $\pm$ 10 % due to transect placement), suggests that the combined revisions best represented the field conditions at transect 2 at the upper two test releases. Figure 1 shows relationships between partial discharge and total bypass flow for each transect for both the revised and original data.

For the 280 cfs release, WUA and other metrics that use velocity criteria had to be re-calculated after the velocities at transect 2 were changed. But because transect 2 comprised a small fraction

Table 1. Partial discharge ratings (cfs) through sections of the Amoskeag bypass in relation to total bypass release

	Total bypass release (cfs) 50	150	280	410
1	23.54	62.65	72.92	83.25
1 (revised)				41.00
2	4.72	8.50	10.57	11.24
2 (revised)			21.18	5.62
3	3.75	26.49	74.39	141.48
4	14.05	71.30	124.71	197.08
5(10)	2.00	6.76	27.27	60.85
6	32.78	146.82	245.72	314.07
7	41.73	113.16	252.25	352.42
8	44.38	153.87	255.39	297.50
9	32.04	95.09	140.55	144.85

Figure 1. Data from Table 1 graphed on $\log_{10}$ scale shows the expected monotonic increase in partial discharge with total discharge at all cross-sections for revised data (A), but not for the original data (B). Habitat models from 280 cfs and 410 cfs releases were revised by recomputing WUA after adjusting velocities up or down at transects 1 and 2, as explained in the text.



of total bypass area, alterations to the aggregated values of habitat metrics across the whole bypass were minor. Specific changes are noted later in the results.

Habitat Conditions at 410 cfs

Local variation in habitat conditions across transects, and variation among transects at larger scales, is graphically represented by the series of plots in Figure 2. The larger main plot for each transect gives the cross-sectional trace of the stream-bed elevation and the associated WSL that reproduces the series of empirical depth measurements. The mid-column velocity at each vertical location is shown as a histogram, with the x and y coordinates showing horizontal distance from the headpin and velocity in ft/s, respectively. Two smaller plots show the distribution of the channel index values that represent substrate and cover characteristics. Two such indices were used, depending on the specifics of the HSC used in habitat models. Recall from the primary report that PCA CLASS was derived from multivariate analysis of joint frequency data for dominant and sub-dominant particle size and cover type variables. The SUBCOV variable was derived from the same input data but emphasized the dominant texture of the substrate in the vicinity of a measurement point.

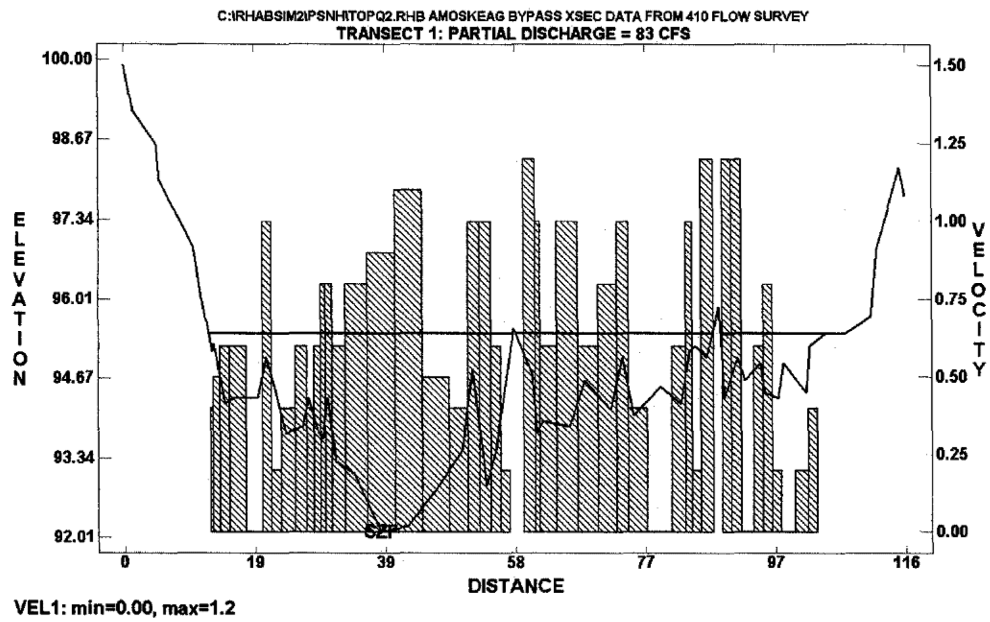
Both methods of channel indexing emphasized the coarse texture of the bypass, especially in areas close to the dam that are heavily scoured such that large boulders and bedrock ledge resistant to movement predominate. Cobble and gravel substrates are largely confined to the smaller exit channels, and fines (sand and silt) are retained only along some stream margin areas. Scaling of the two indexing criteria was such that they were approximately inversely related to each other. Interestingly, although PCA CLASS takes on fewer values than SUBCOV, it gives descriptions of variation that are more spatially heterogeneous. This is because PCA CLASS is more responsive to other forms of local variation than SUBCOV (e.g., shifts in sub-dominant frequency, co-occurrence of multiple cover types), which focuses more on gross particle-size dominance, thus ignoring variation in the more subtle attributes picked up by PCA CLASS.

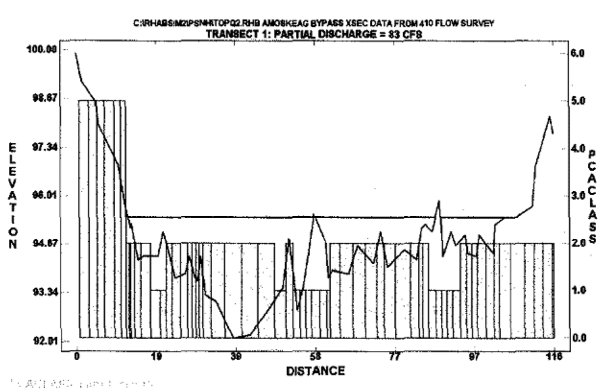
The hydraulic characteristics of various sub-channels and habitat areas generated by RHABSIM methods provide direct estimates of habitat change with increasing test flow rate (Table 2). While these data are specific only for the selected locations, nearby areas with similar cross-sectional geometry should have qualitatively similar characteristics and responses to flow.

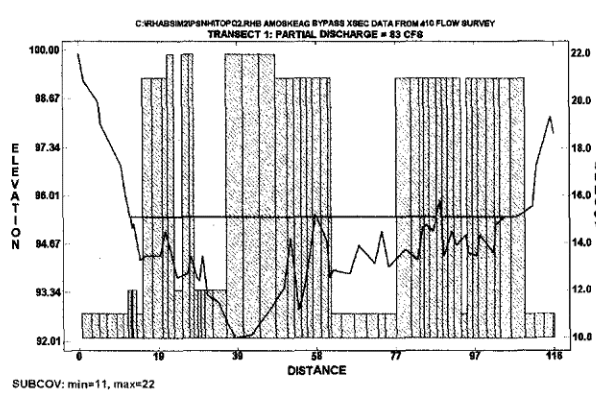
Most variables increase monotonically with increasing discharge, but exceptions did occur (e.g., with average depth and velocity and maximum velocity, or for derivatives like hydraulic radius). Stage (WSL) tended to increase with flow, but these values are not reliable indicators of depth increases because they are averaged over what in many cases are multiple threads of flow at different elevations. Ideally, variables such as wetted perimeter, top-width, and cross-sectional area should increase monotonically with flow, but uncertainty in estimating the water's edge location along rubble-strewn stream margins (in addition to rod placement variation and small-scale disturbance of rocks) can yield data that do not meet that expectation.

Considering the data set in its entirety, the greatest changes in hydraulic characteristics occurred between the 50 cfs and 150 cfs releases. This conclusion was supported by results of PCA on the hydraulic variables (Figure 3). The correlation structure (factor loadings shown in the upper panel) is consistent with the joint influences of local channel geometry (i.e., difference among riffles, runs, and pools) and increasing discharge. The separation of sample scores grouped by transect in relation to the directions of change in hydraulic variables (represented by the arrows in the factor loading plot) reveals patterns of hydraulic variation related to differences in transect

Figure 2 (series). Cross-section plots of habitat variables used in RHABSIM at 410 cfs.







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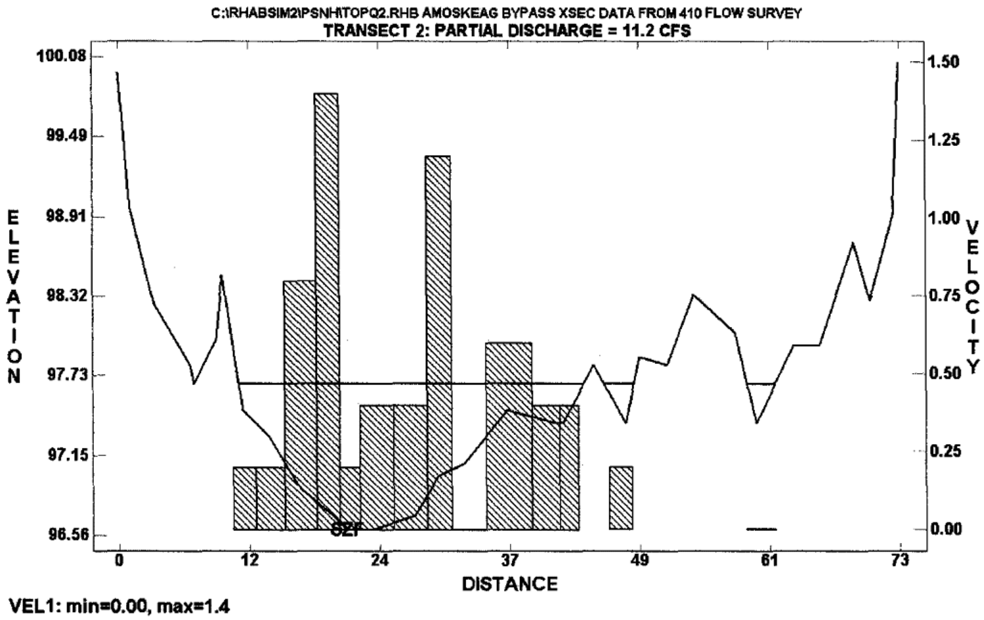

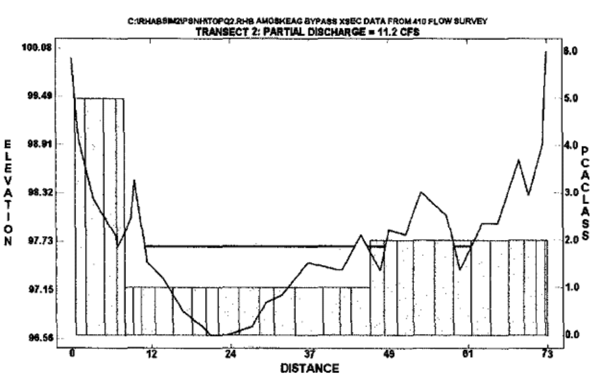

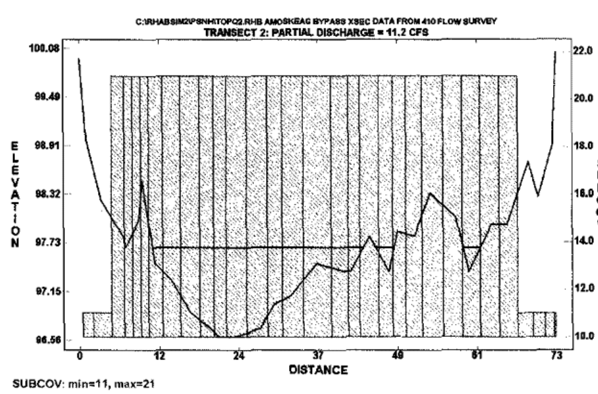

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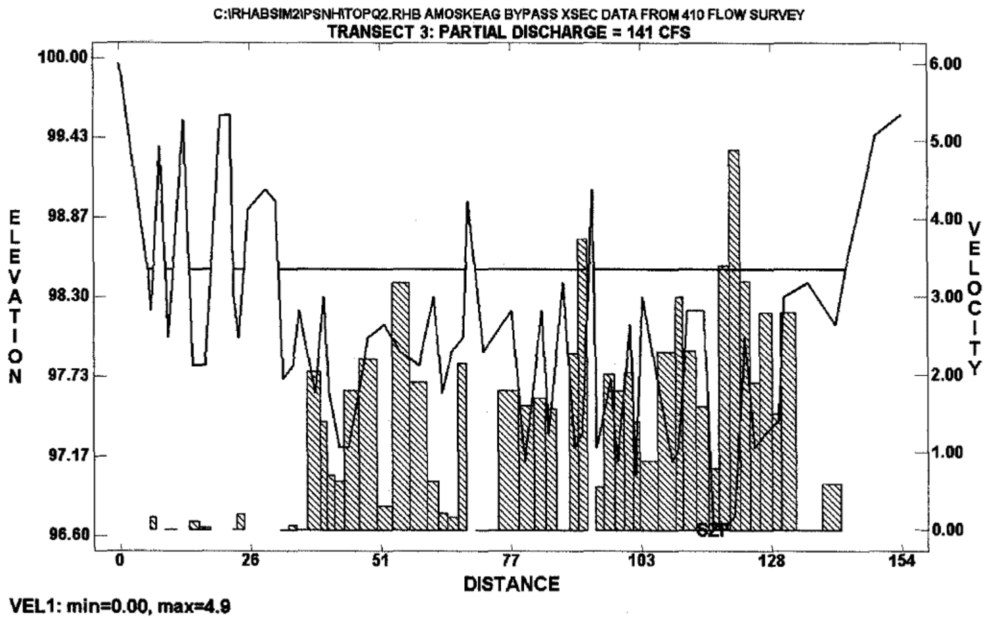

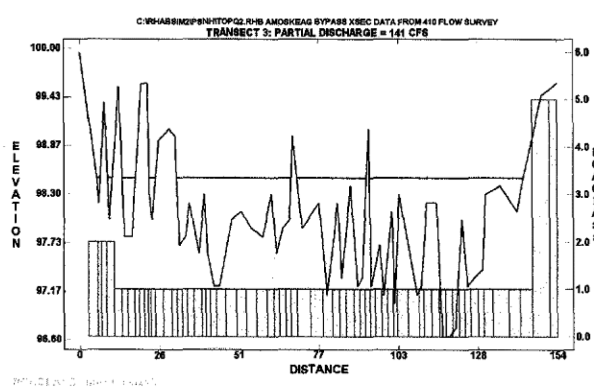

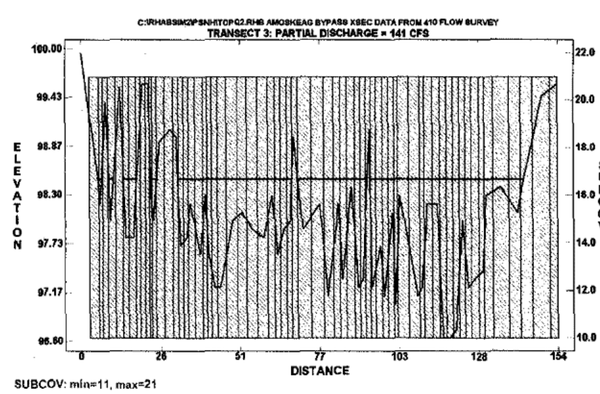

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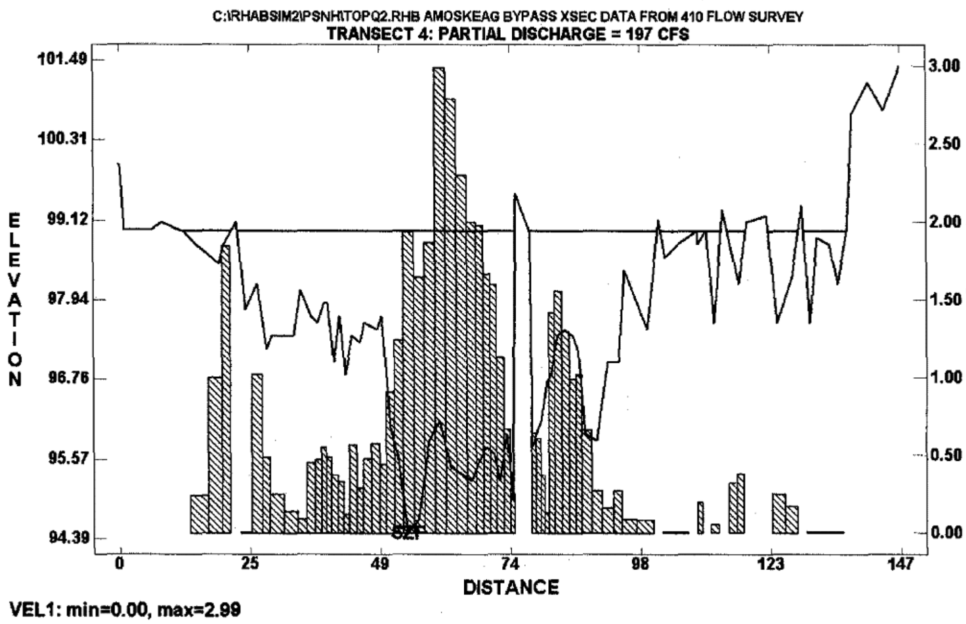

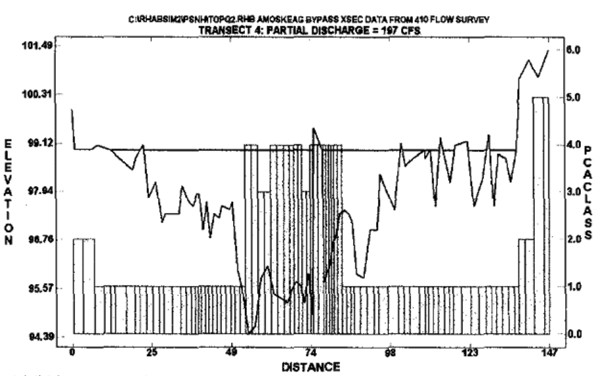

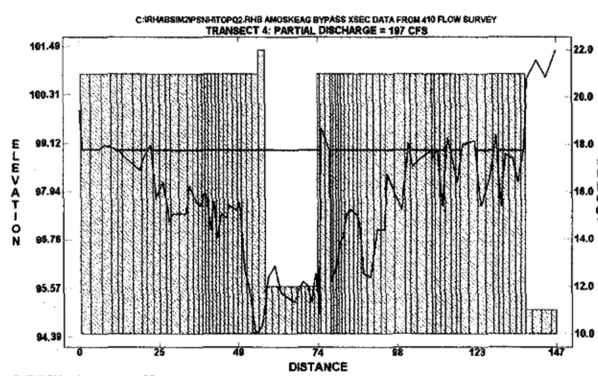

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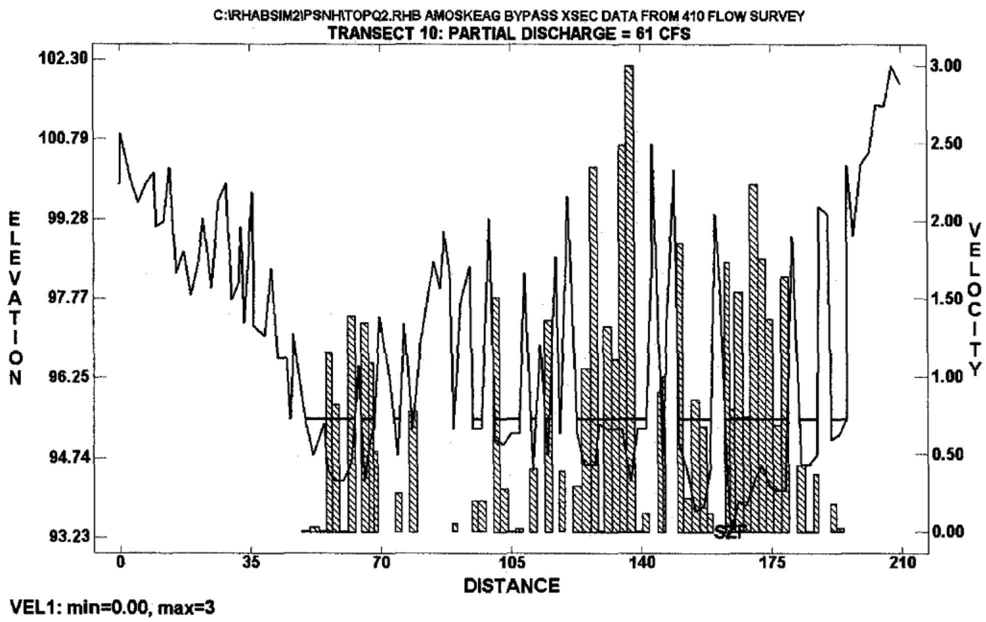

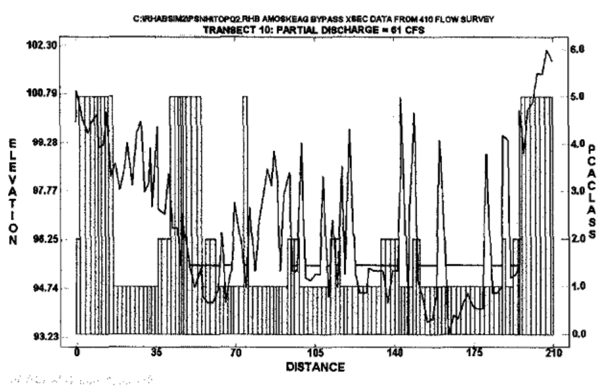

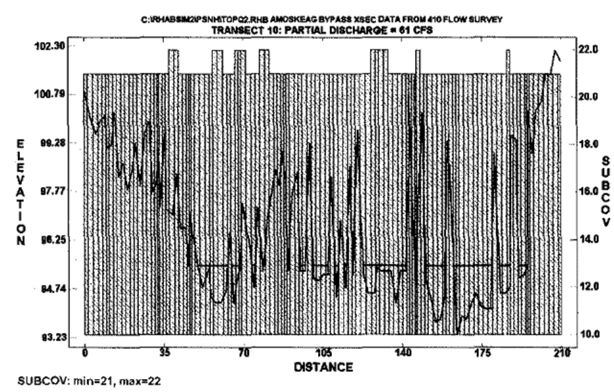

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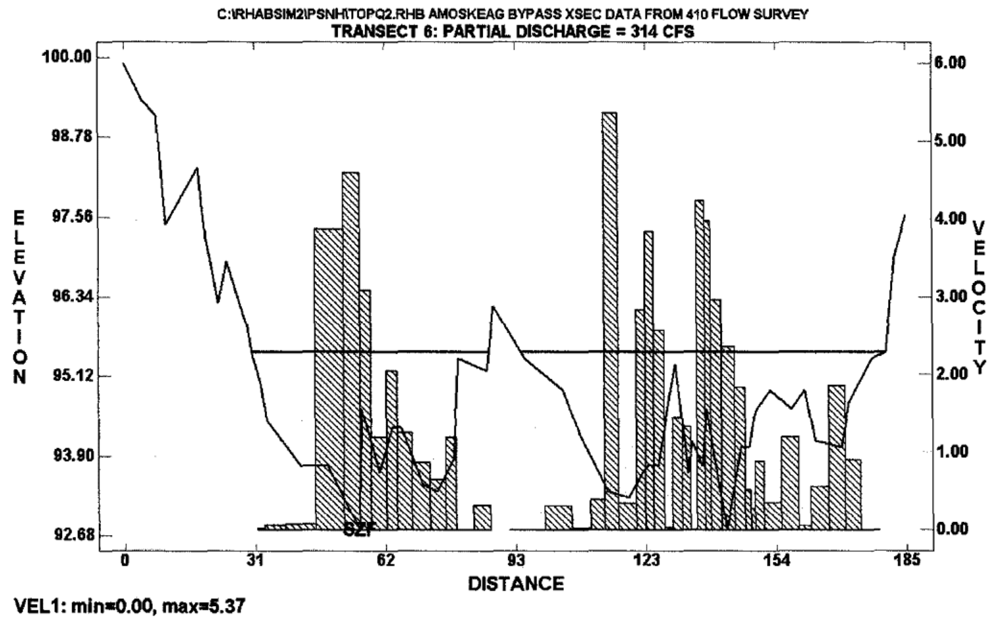

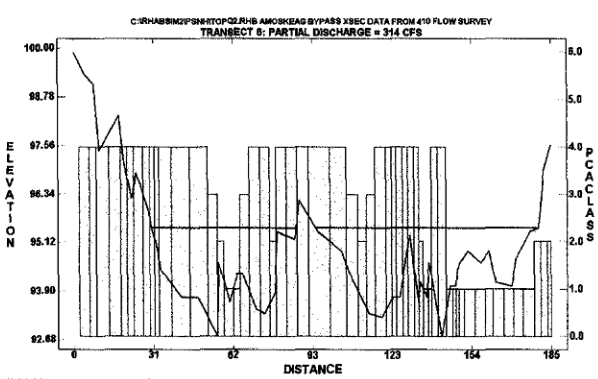

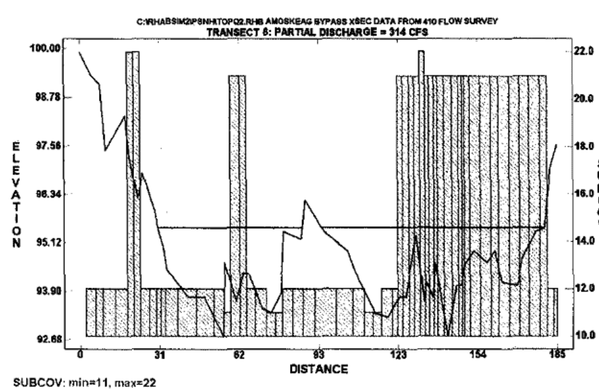

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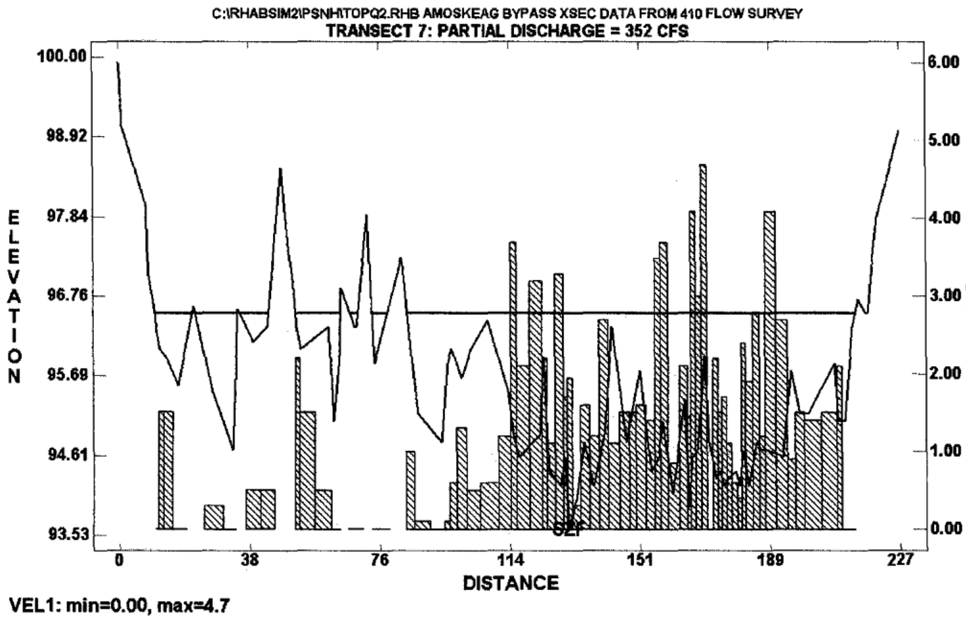

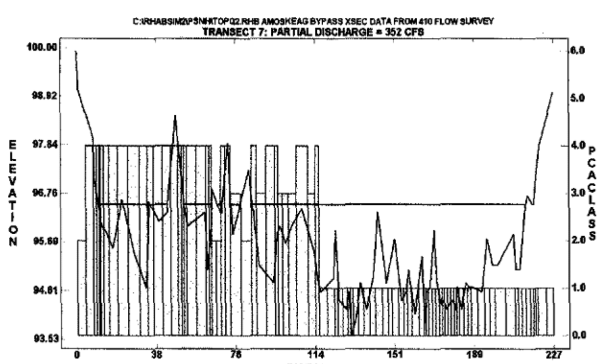

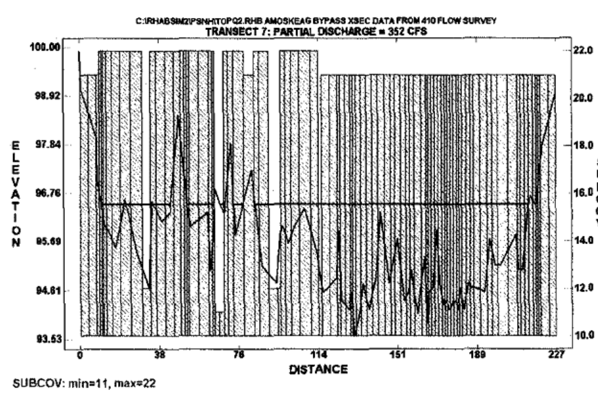

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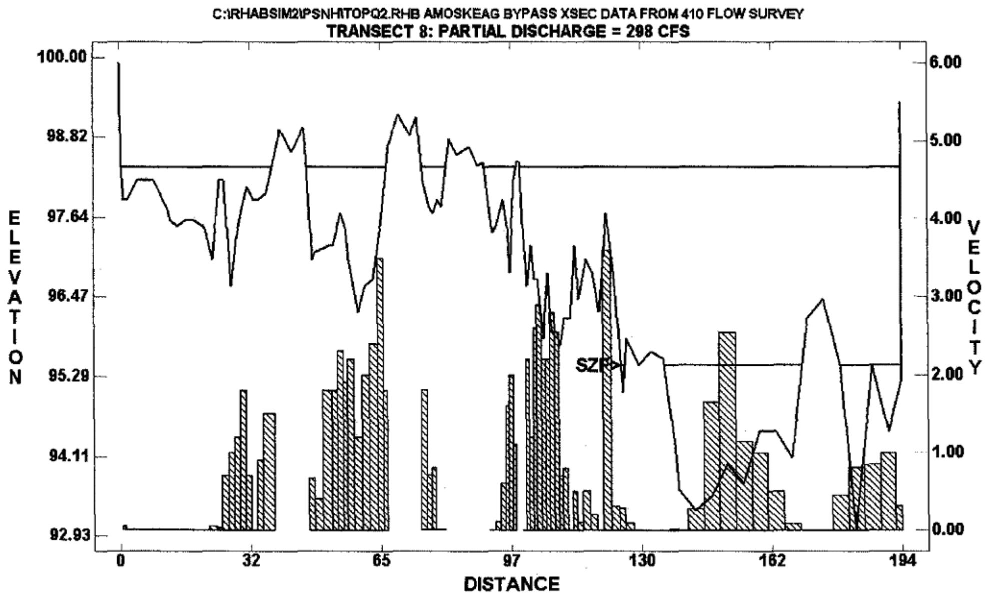

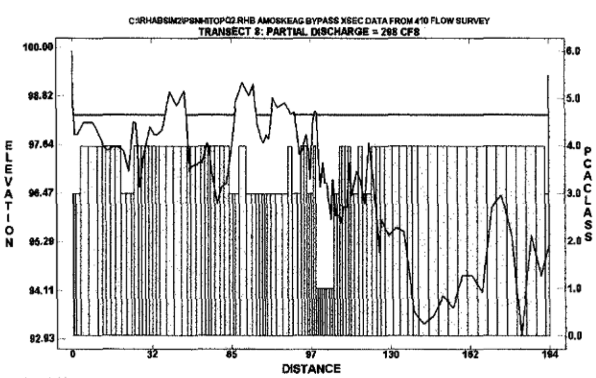

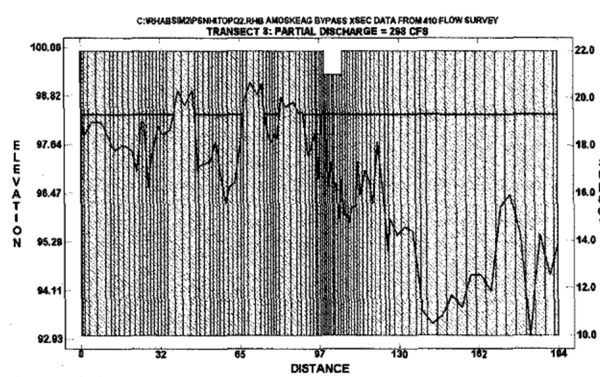

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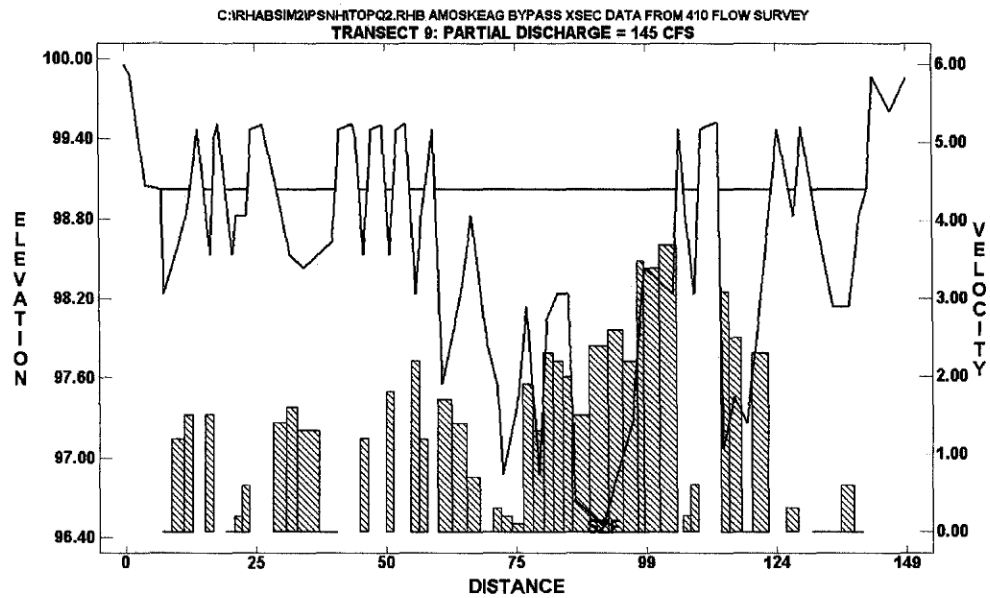

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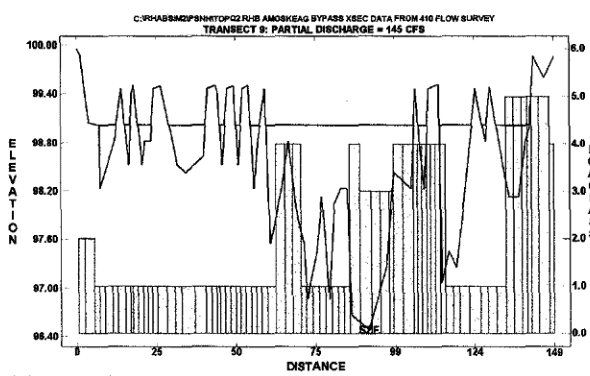

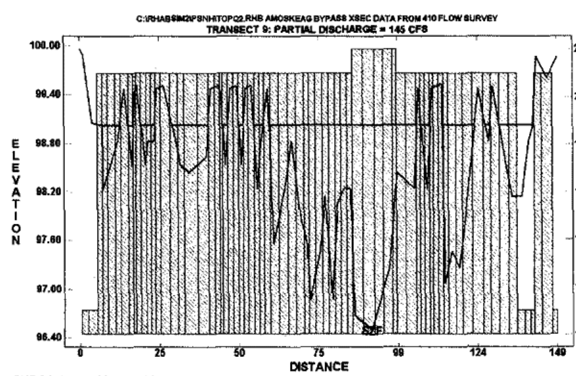

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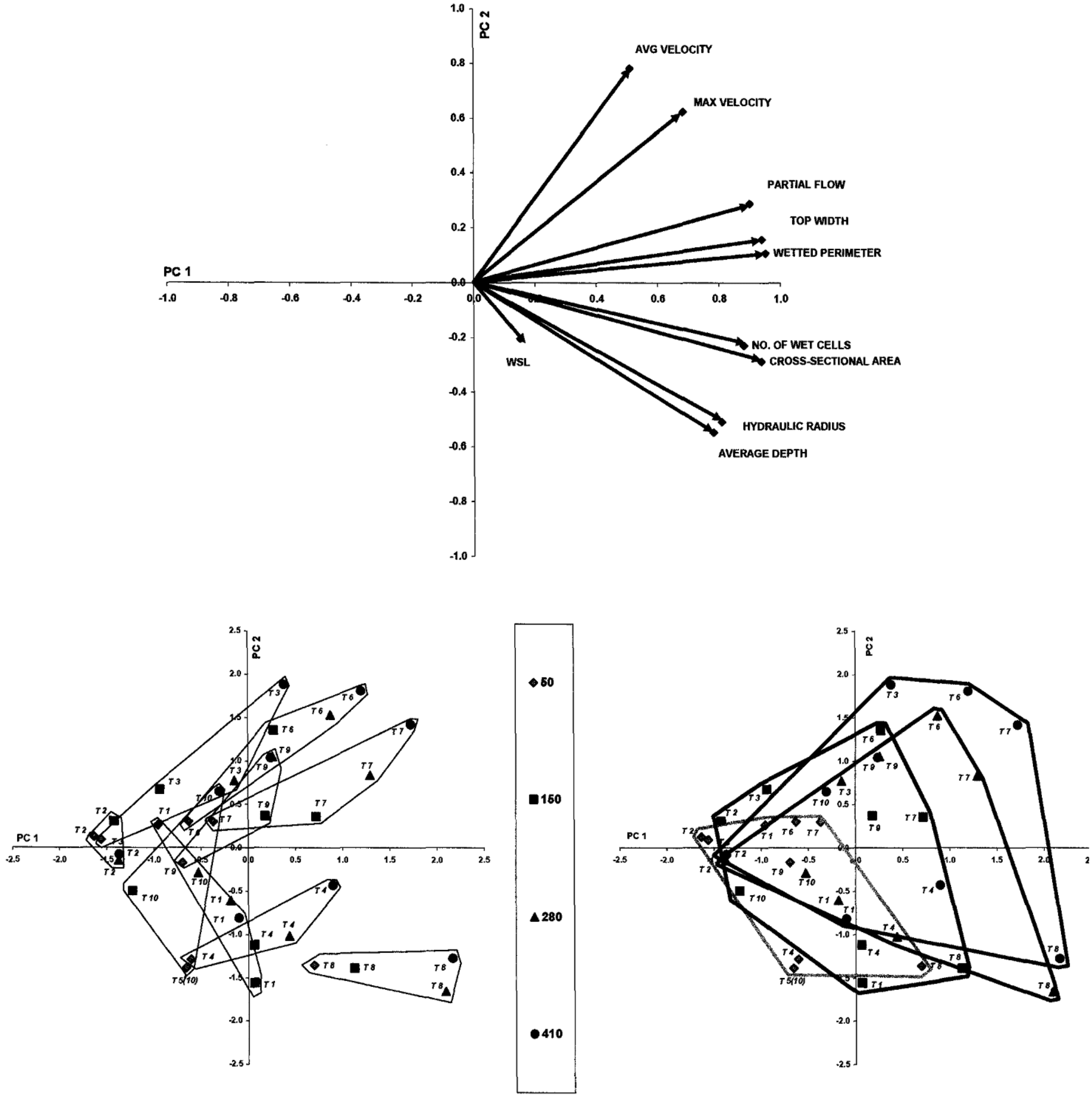
Table 2. Hydraulic characteristics of transects in the Amoskeag bypass at four test flows.

Test flow (cfs)	Cross-section	Stage (WSL)	Partial flow (cfs)	Wetted cells (N)	Wetted perimeter (ft)	Cross-sectional area (ft2)	Top width (ft)	Hydraulic radius	Average depth (ft)	Velocity (ft/s) average	Velocity (ft/s) maximum
50	1	94.26	23.5	24	52.4	40.9	48.2	0.78	0.85	0.58	2.75
150	1	95.76	62.7	47	103.3	158.4	92.3	1.53	1.72	0.40	1.10
280	1	95.23	72.9	44	93.6	112.5	86.9	1.20	1.29	0.65	1.60
410	1	95.41	83.3	45	97.5	124.6	89.8	1.28	1.39	0.67	1.20
50	2	97.06	4.7	7	18.4	8.5	18.2	0.46	0.46	0.56	1.50
150	2	97.32	8.5	10	28.6	14.4	28.3	0.50	0.51	0.59	2.30
280	2	97.61	10.6	16	40.5	21.4	40.2	0.53	0.53	0.49	1.23
410	2	97.66	11.2	14	38.0	20.9	37.7	0.55	0.56	0.54	1.40
50	3	96.83	3.8	20	33.0	9.8	29.3	0.30	0.33	0.38	1.50
150	3	97.34	26.5	31	65.4	28.7	59.1	0.44	0.48	0.92	2.40
280	3	98.33	74.4	47	116.0	70.1	111.0	0.60	0.63	1.06	3.00
410	3	98.50	141.5	50	126.3	83.7	117.9	0.66	0.71	1.69	4.90
50	4	97.08	14.1	36	58.3	72.4	49.6	1.24	1.46	0.19	2.07
150	4	97.92	71.3	54	93.1	124.4	79.2	1.34	1.57	0.57	2.10
280	4	98.50	124.7	56	106.8	156.4	89.7	1.46	1.74	0.80	2.24
410	4	98.99	197.1	63	131.5	186.6	114.2	1.42	1.63	1.06	2.99
50	5	97.64	2.0	54	91.4	75.8	83.3	0.83	0.91	0.03	0.50
150	10	96.20	6.8	29	55.5	32.1	50.1	0.58	0.64	0.21	1.10
280	10	97.46	27.3	50	92.3	63.6	83.0	0.69	0.77	0.43	2.14
410	10	95.43	60.9	53	97.4	64.8	84.3	0.67	0.77	0.94	3.00
50	6	93.85	32.8	27	90.4	70.8	85.4	0.78	0.83	0.46	2.90
150	6	94.45	146.8	33	109.9	117.0	106.0	1.06	1.10	1.25	4.90
280	6	95.37	245.7	41	138.8	162.9	135.8	1.17	1.20	1.51	4.90
410	6	95.48	314.1	42	147.8	184.7	142.3	1.25	1.30	1.70	5.37
50	7	95.15	41.7	47	109.9	74.1	107.0	0.67	0.69	0.56	2.60
150	7	96.42	113.2	65	171.9	160.6	166.1	0.93	0.97	0.70	3.70
280	7	96.38	252.3	66	173.8	206.4	167.9	1.19	1.23	1.22	4.20
410	7	96.53	352.4	70	192.5	226.3	181.6	1.18	1.25	1.56	4.70
50	8	96.41	44.4	60	131.6	218.3	119.4	1.66	1.83	0.20	3.75
150	8	96.97	153.9	61	136.6	260.2	124.2	1.90	2.09	0.59	3.10
280	8	98.13	255.4	85	178.0	376.5	165.0	2.11	2.28	0.68	3.22
410	8	98.43	297.5	83	181.9	368.4	166.2	2.03	2.22	0.81	3.60
50	9	96.06	32.0	39	94.2	61.5	81.7	0.65	0.75	0.52	1.40
150	9	97.46	95.1	59	137.8	104.2	124.8	0.76	0.83	0.91	2.70
280	9	96.79	140.6	51	123.5	101.7	110.5	0.82	0.92	1.38	3.40
410	9	99.04	144.9	45	108.1	95.4	99.8	0.88	0.96	1.52	3.70

geometry. Within each transect group, scores are coded by flow, so the position of flows within transects (in relation to the arrows in the upper panel) shows how the various hydraulic conditions tended to change within transects across the range of test flows. For example, the scores for transect 8 (which crossed a large deep pool) are separated from other scores largely on the basis of high values for average depth and hydraulic radius. Within several groups of transect scores, the scores for the corresponding test flows are arranged along a gradient representing increasing average and maximum velocity. For the most part, these included shallower transects representing riffles and runs. Transects where the scores among flows are tightly grouped are those where hydraulic conditions did not change as much with flow compared to other locations (e.g., transect 2). Grouping scores by test flow over all transects (lower right panel) depicts the overall range of conditions surveyed by all locations, and shows the relative incremental influence of increasing test flow on hydraulic conditions in the bypass as a whole, as well as within the parts (habitat patches represented by transects) which make up the whole. Note that the validity of this representation depends greatly on how well the selected transects actually

Figure 3. Upper panel: factor loading plot of the correlations between RHABSIM hydraulic habitat variables and the first two axes of PCA on the data in Table 2. Lower panels: sample scores show the locations of each transect and test release in the space of the first two PCA axes. Convex polygons surround samples grouped by transect (left) and by test release (right).



represent local habitat variation within the bypass. The coherent behavior of the measured variables (i.e., relationships within and between transects across flows makes sense) suggests that the relationships depicted in Figure 3 are qualitatively accurate, even if alternative representations (such as would be provided by a different set of transects) were to change the numbers. That is, similar relationships would be expected to emerge due to the consistency of constraints imposed on hydraulic variation by channel geometry and discharge.

Variation in Wetted Surface Area

Water levels attained by incremental increases in discharge through a channel represent boundary conditions that place an upper limit on habitat area and volume for aquatic organisms. In a bedrock-controlled channel like the Amoskeag bypass, the simple relationship between flow and wetted area provides a stable context which constrains variation in other ecological criteria that vary with flow. Characterizing that constraint is thus a first step toward understanding how the system of evaluation criteria used in this study responds to changes in bypass flow.

The change in total area (actually, an index normalized to 1,000 ft of channel length) with change in test flow as depicted by the RHABSIM model is shown in Figure 4. The upper panel represents a summation of the individual transect data shown in the lower panel. The rate of increase (as depicted by the slope of the line joining adjacent points on the upper graph) is almost constant between 50 cfs and 280 cfs (about 177 ft^{2}/1000 ft per cfs), then decreases to about 53 ft^2/1000 ft per cfs between 280 cfs and 410 cfs.

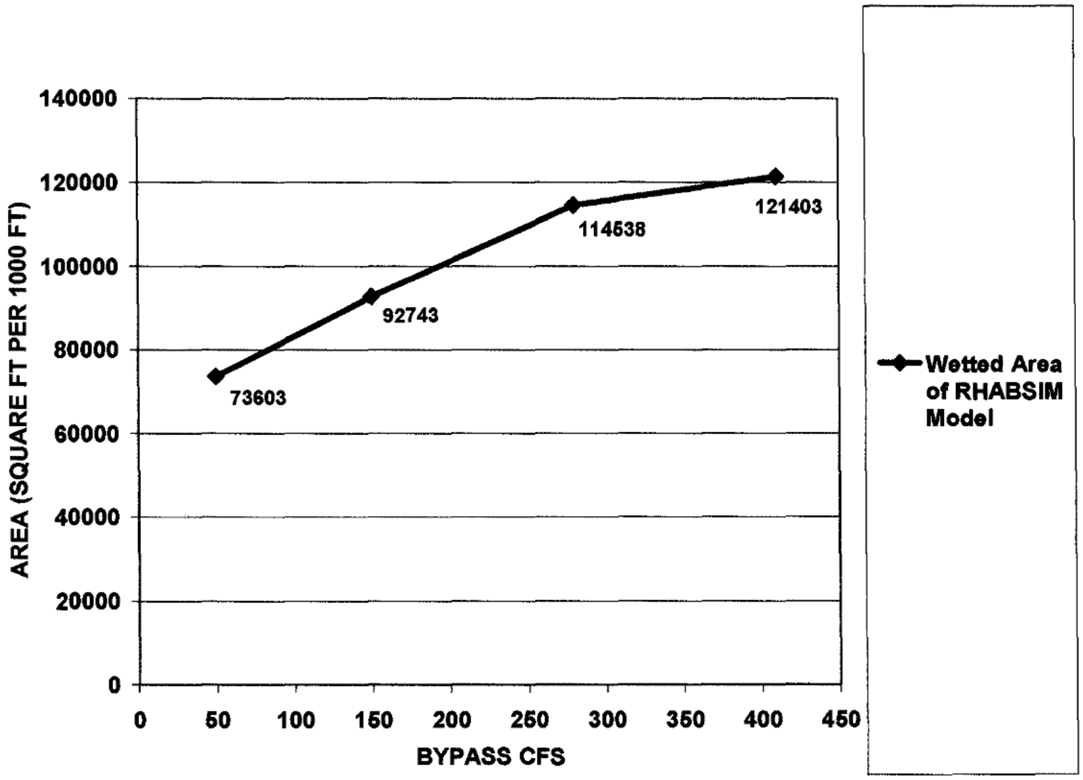
Variation in Key Habitat and Generalized Habitat

Although the responses to flow change for these two sets of evaluation criteria are first presented individually, they are later analyzed together in a systemic fashion because of fundamental similarities in their definitions. Unlike biological HSC, which use a composite suitability function to constrain the amount of WUA that an RHABSIM cell can contribute to totals at higher levels of organization (e.g., at transects or for the entire bypass), key habitat and generalized habitat types are structured so that individual model cells fall into classes defined by their depth, velocity, and substrate-cover characteristics (see primary report for more detailed descriptions). In the case of key habitat types, definitions are not mutually exclusive and do not cover all potential combinations of habitat variables. Rather, they represent combinations of habitat conditions that empirical studies have shown are used heavily by species dependent on riverine environments (Bain and Knight 2000). Areas of key habitats therefore do not add up to total bypass area in the model.

Unlike key habitat types, generalized habitat types are defined to be mutually exclusive and to represent all potential combinations of habitat conditions. Thus, within rounding errors specific to the way RHABSIM codes habitat criteria, the sum of generalized habitat areas will equal the total area for a given test release. Depth and velocity limits for generalized habitat types were set to be similar to the limits defining key habitats, as explained in the primary report. Unlike WUA based on biological HSC, where WUA can be less than cell area, key habitat and generalized habitat criteria nominally return total cell areas if they meet the classification criteria, or return zero area if they do not (minor exceptions occur due to the method of interpolation used in RHABSIM).

Key habitat areas either increased or decreased with test discharge in a manner which reflected their definitions (Figure 5). The area of shallow-coarse, shallow-fast, and deep-fast habitat all increased with discharge, while the area of slow-cover and shallow-slow habitat remained flat or

Figure 4. Upper panel: total wetted area from the RHABSIM model of the Amoskeag bypass in relation to test flow releases of 50, 150, 280, and 410 cfs. Lower panel: breakdown by transect.



TOTAL AREA AND BYPASS CFS (SQUARE FT PER 1000 FT)

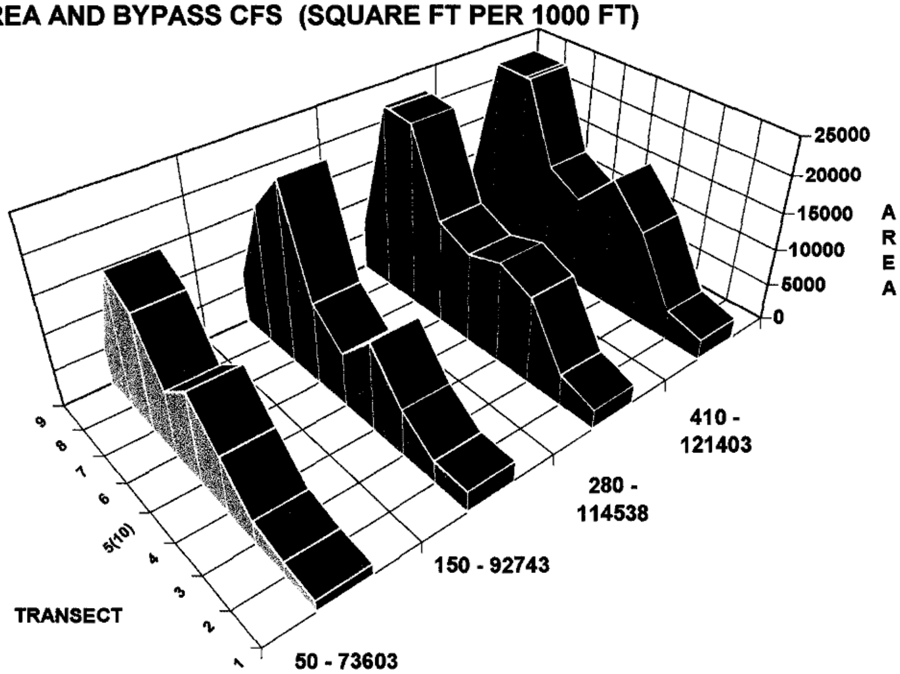
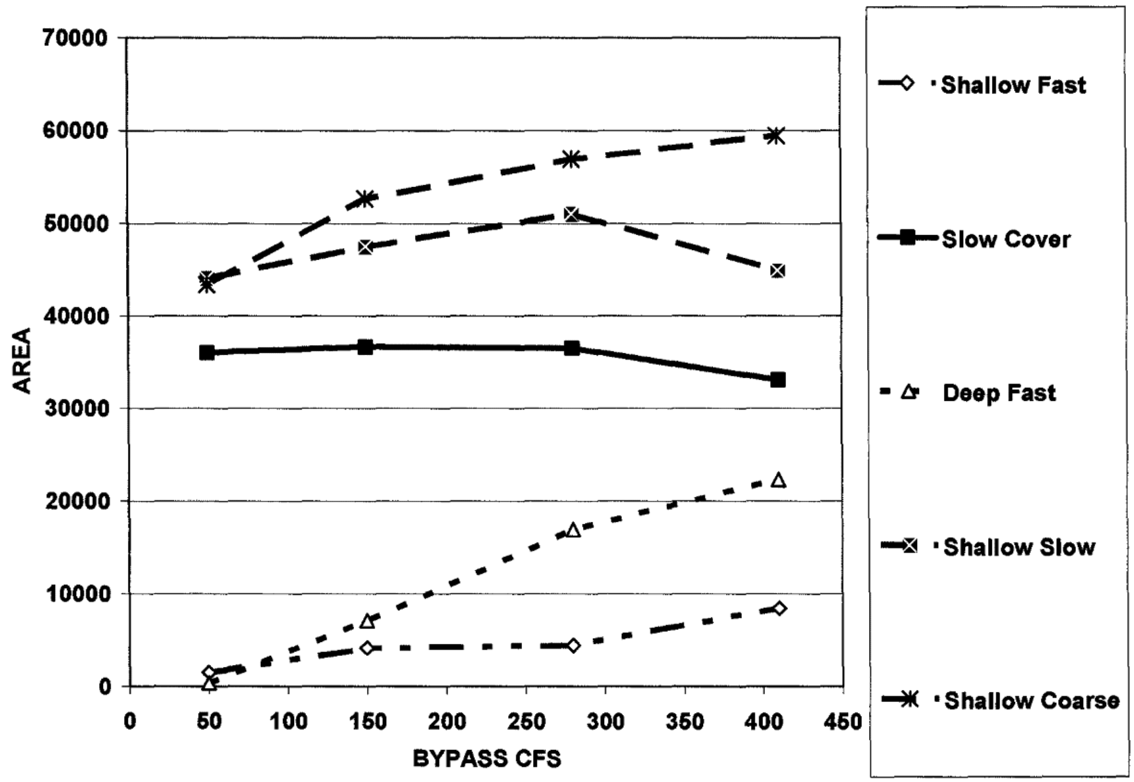


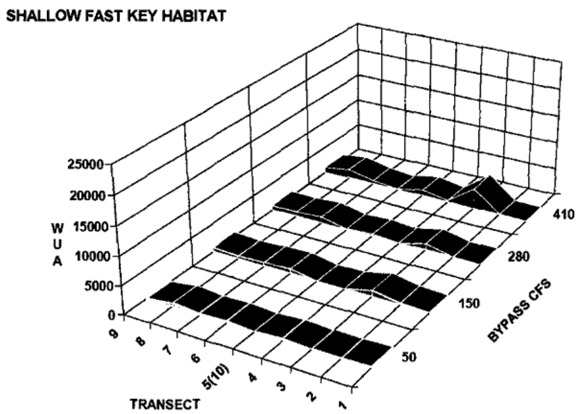
Figure 5. Area of key habitat types in relation to test flows of 50, 150, 280, and 410 cfs into the Amoskeag bypass. Key habitat types were defined in the primary report.

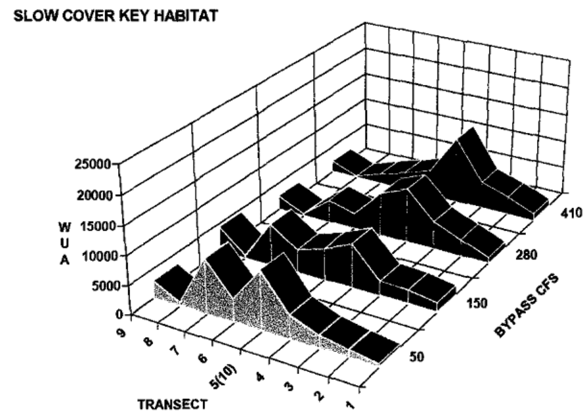


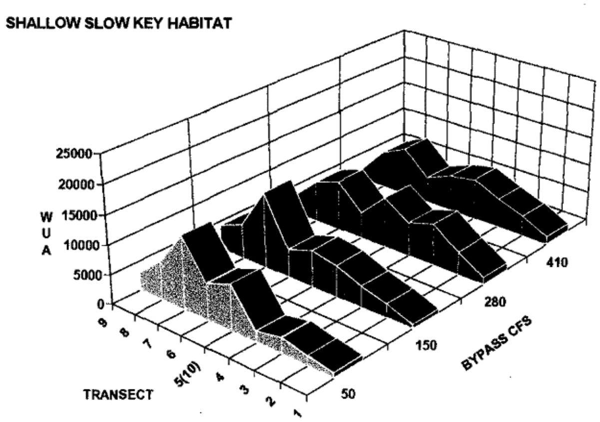
increased between 50 and 280 cfs. Area of slow-cover and shallow-slow habitat then decreased between 280 cfs and 410 cfs. However, with the exception of deep-fast habitat, the relative amounts of the key habitat types were generally similar across the range of test releases, and differences among transects generally were persistent (Figure 6). Thus, increasing test flow resulted largely in the creation of more deep-fast and shallow-fast habitat without seriously changing the amounts of other key habitat types (Figure 7).

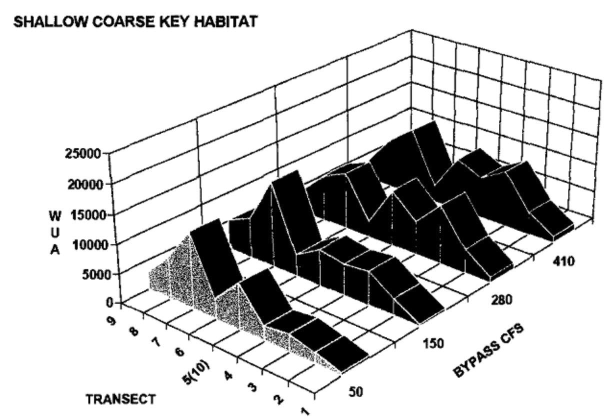
Relative to key habitat types, the set of generalized habitat types responded similarly to variation in test flows (Figure 8, see figure caption for abbreviations used here in the text). Types that changed noticeably (as indicated by spread along the y-axis) as flow increased included SSCP (which decreased), SSCA (which increased markedly above 50 cfs but varied little between other releases), SMCP and SMCA (both of which increased), MSCP (which showed a moderate peak at 280 cfs), MSCA (showing a saddle-shaped response with peaks at 50 cfs and 410 cfs), and MMCP (strong, nearly linear increase). Types MFCP, DSCA, DMCA, and DMFA showed smaller increases, primarily at the two higher test flows. Amounts of other generalized habitat types did not change much or were not present at any flow. At a coarser level of resolution, however, it is apparent that the overall characteristics of the bypass (as represented by RHABSIM transects) are relatively similar across all test flows, with the largest differences associated with the increase from 50 cfs to 150 cfs for some generalized types. This mirrors the perception of habitat variation provided by the system of key habitat types.

Figure 6. Areas of key habitat types by transect in relation to test releases into the Amoskeag bypass of 50, 150, 280, and 410 cfs.









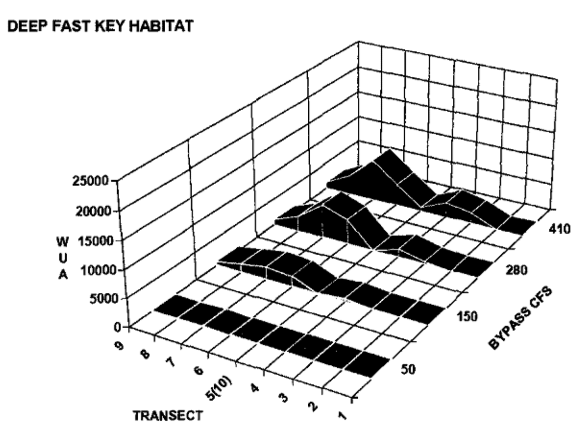
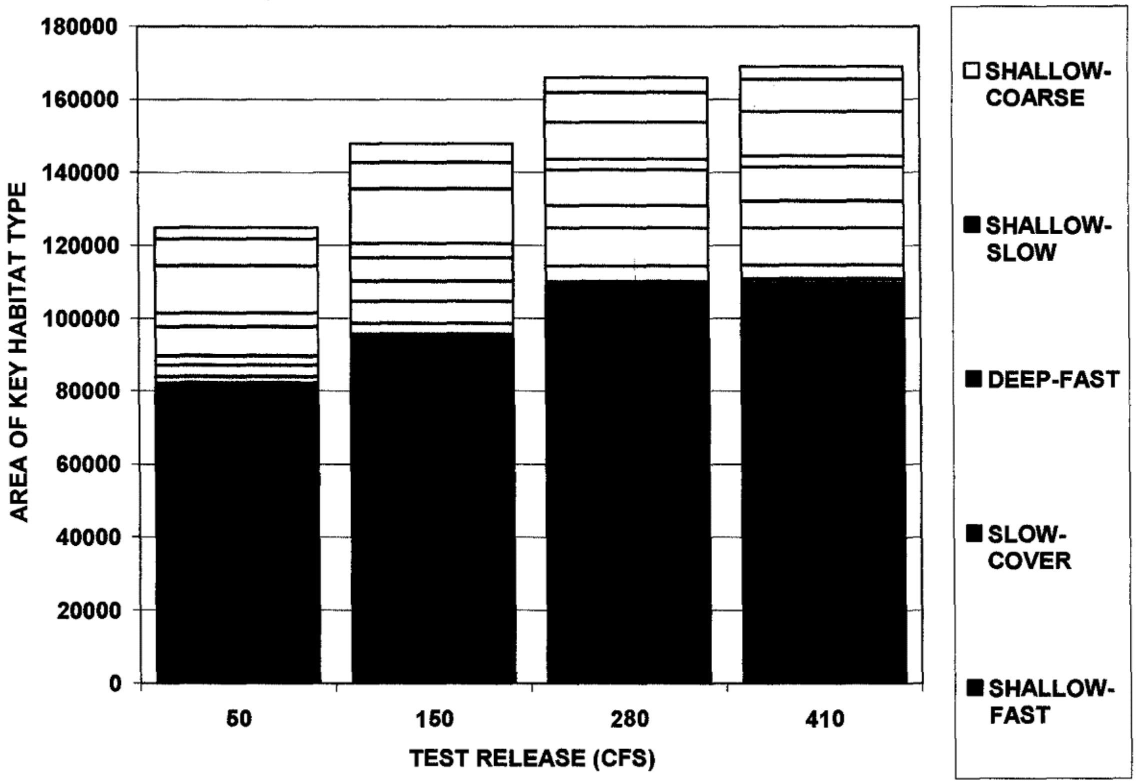


Figure 7. Relative change in key habitat composition with changing test flow release within the Amoskeag bypass. The widths between horizontal cross-hatching within a color band represent the contributions from individual transects to the bypass total, which corresponds to the height of each multi-colored bar. Bypass totals, however, are less than total bypass area because key habitats are not mutually exclusive and do not include all combinations of habitat conditions.



Variation in Biological Evaluation Criteria

Results of habitat modeling and assessment based on HSC and WUA for biological evaluation criteria—species and life stages for fish or higher taxonomic categories and general diversity criteria for benthic macroinvertebrates—are presented in the following sub-sections. These results provide, on a case-by-case basis, the mechanistic details for a more integrative framework that focuses on the bypass and the entire set of evaluation criteria as a higher level of system organization, which is presented in the next section.

Benthic Macroinvertebrates

Using HSC presented in the primary report (from Gore et al. 2001), WUA for three orders of benthic macroinvertebrates and general macroinvertebrate diversity was a monotonic function of increasing test flow (Figure 9). Except for general diversity, which was more constrained than the other macroinvertebrate indices, the differences between the 280 cfs and the 410 cfs test conditions were likely within the range of uncertainty associated with the specific location of transects (Williams 1996). Response functions for Ephemeroptera and Trichoptera were nearly identical at both the bypass and individual transect levels of resolution. As shown in the transect-specific results, constraints on habitat availability for all macroinvertebrate criteria were jointly imposed by discharge, mesohabitat type, and interactions between the two. An explanation for considering WUA as an index of constraint on habitat availability is presented in Box 1.

Figure 8. Variation in generalized habitat types in relation to test flows (cfs) in the Amoskeag bypass (see legend). The y-axis denotes total area as ft^2/1,000 ft. Generalized habitat types are designated on the x-axis by the following conventions: first letter = depth category (S = shallow, M = medium, D = deep); second letter = velocity category (S = slow, M = medium, F = fast); third letter = substrate quality (F = fine, C = coarse); fourth letter = cover category (P = present, A = absent). See primary report (page 11) for definitional criteria of generalized habitat types.

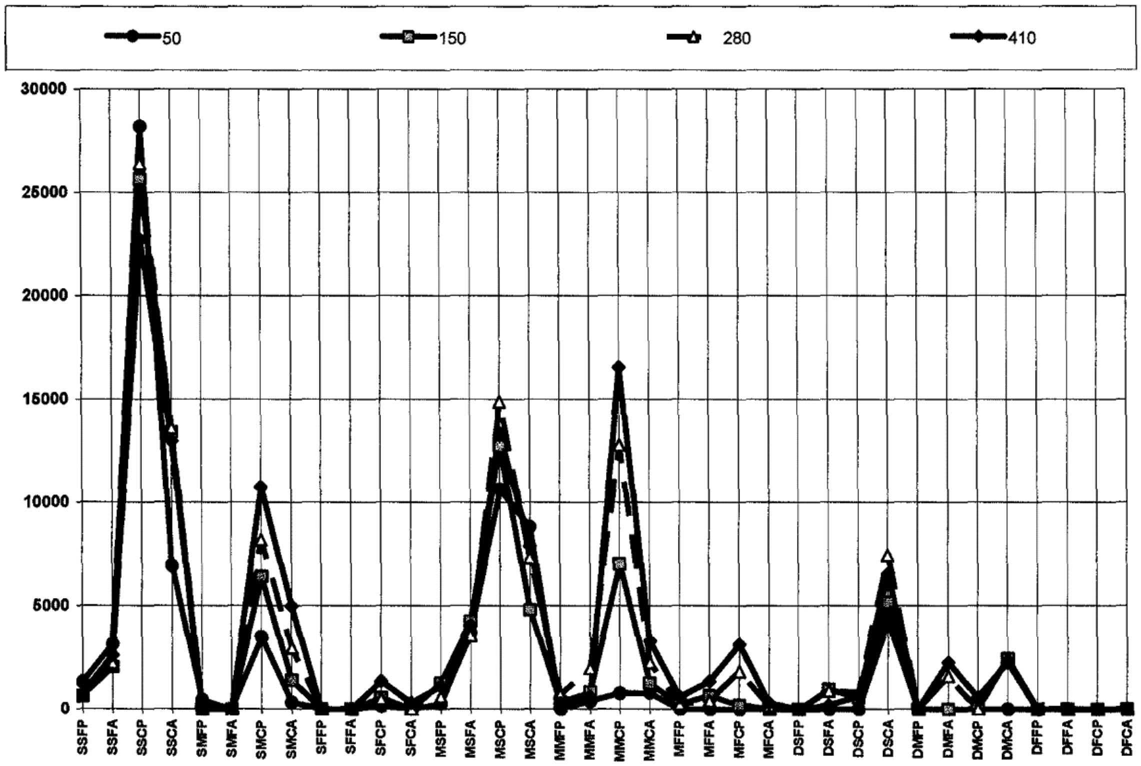


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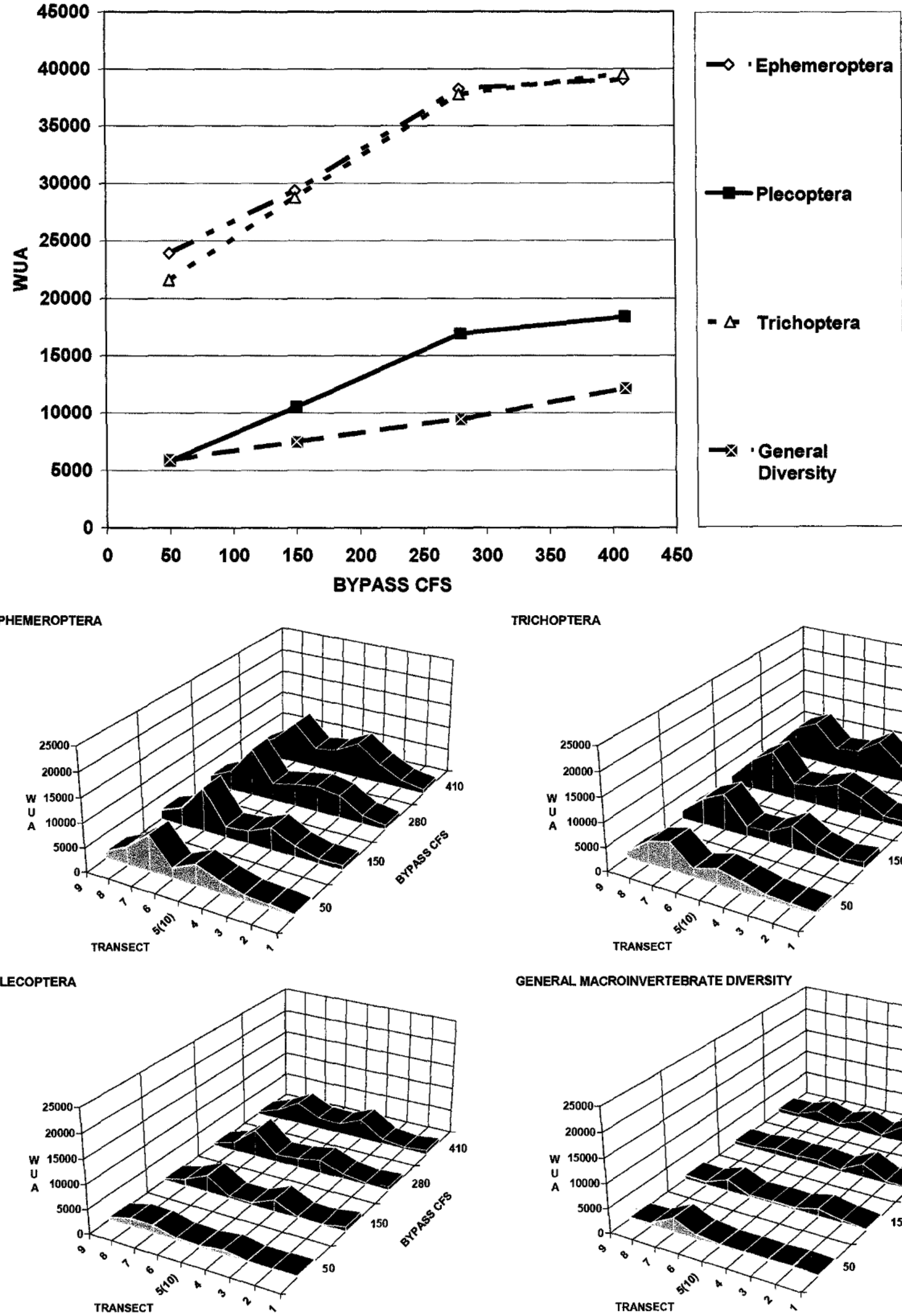
Figure 9. Upper panel: overall flow versus WUA relationships for three aquatic insect orders and general macroinvertebrate diversity, aggregated over the entire bypass reach. Middle and lower panels: relationships by transects representing meso-scale habitat variation within the bypass.



Smallmouth Bass

As mentioned in the primary report, two sets of HSC were evaluated for spawning, fry, juvenile and adult life stages of smallmouth bass. Figure 10 organizes the flow versus WUA relationships for the first set of criteria. Figure 11 follows the same format for relationships based on the alternative criteria.

Both sets of criteria produced similar results for both the bypass and individual transects. The main differences were that the first set of spawning criteria was more sensitive to flow change than the second set, while the alternative fry criteria were more sensitive than the first set for that life stage. Both sets of criteria for juveniles and adults produced similar unresponsive (nearly flat) flow versus WUA relationships, with habitat availability for adults constrained to be found mainly in the large deep pool represented by transect 8. Constraints imposed on habitat availability for adults and juveniles were more severe than for spawning and fry life stages, reflecting that much of the bypass is either too shallow at low flows, or too swift at higher flows, to be considered as anything more than marginally suitable, especially for adults. However, the large pool at transect 8 provides habitat conditions that remained relatively stable over the range of test flows (Figure 12). Generally, the greatest habitat availability for all life stages of smallmouth bass was found at transect 8 or transect 4, which crossed another narrow, short pool. Peak velocities at transect 4 at 410 cfs were increased by a "funneling" effect tied to the shape of the cross-section, so that suitable habitat for smallmouth bass was found more along the channel margin adjacent to the thalweg.

Fallfish

Flow-versus-WUA relationships for fallfish are presented in Figure 13. Habitat availability was much more constrained using reproductive and spawning-incubation HSC than criteria for adults, for which WUA peaked mildly at the 280 cfs release. Constraints on habitat suitable for reproduction stem initially from a dearth of quality substrate, which is further limited by including depth and velocity suitability criteria (Table 3). Fallfish spawn over nest-mounds constructed of gravel and pebbles, and bed materials of this size are swept free from much of the upper bypass by episodic high flows. Much of the RHABSIM model retaining joint suitability (depth, velocity, and substrate quality considered together) > 0.6 for fallfish spawning and incubation was concentrated at transect 1, which crosses the eastern-most distributary channel at the downstream end of the bypass. This observation was true for all test flows, but because conditions elsewhere in the bypass did not totally exceed limits of tolerance reflected in the HSC, the higher-quality characteristics at transect 1 are not well-represented in the flow versus WUA relationships for individual transects. Further, the small contribution of transect 1 to the total area considered also masks the higher quality of this area for fallfish spawning compared to other, much larger patches where overall quality was much lower. Adult fallfish habitat availability was concentrated mainly in pools (transects 4 and 8).

Common Shiner

Flow-versus-WUA relationships for common shiner varied considerably by life-stage (Figure 14). Considering the entire bypass, WUA for fry and juveniles was essentially flat between 50 cfs and 150 cfs and then declined at similar rates up to 410 cfs. These declines reflect greater sensitivity of younger life stages to increasing velocity and depth, consistent with the nursery function of shallow-slow key habitat in fluvial systems (Bain and Travnichek 2000). WUA increased at similar rates for juvenile and adult common shiners between 50 cfs and 280 cfs, where it reached

Figure 10. Upper panel: flow versus WUA relationships for four life stages of smallmouth bass for the entire Amoskeag bypass, using the first set of HSC models. Middle and lower panels: relationships by transect representing meso-scale habitat variation within the bypass.

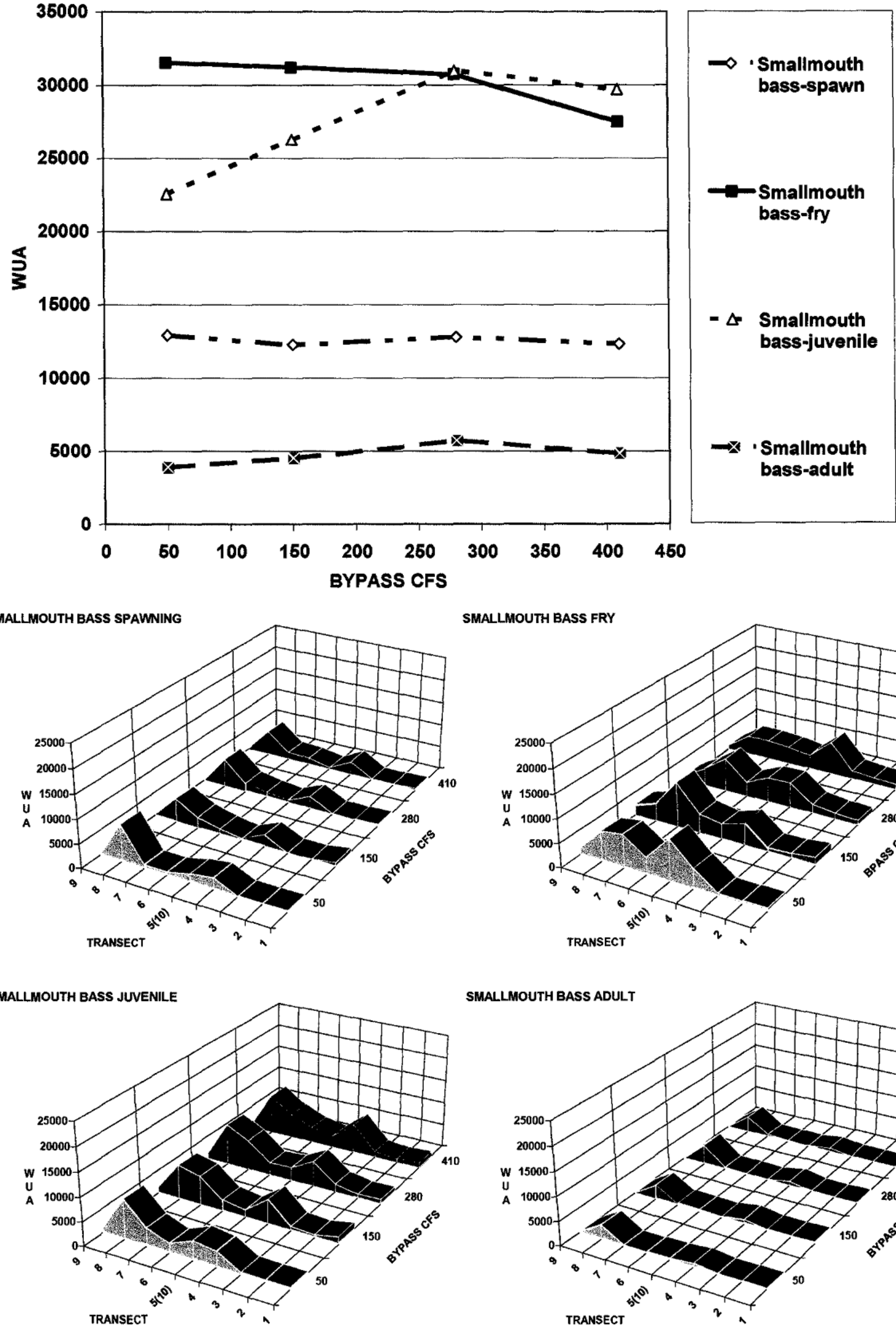


Figure 11. Smallmouth bass flow versus WUA relationships, as organized in Figure 10, based on an alternative set of HSC.

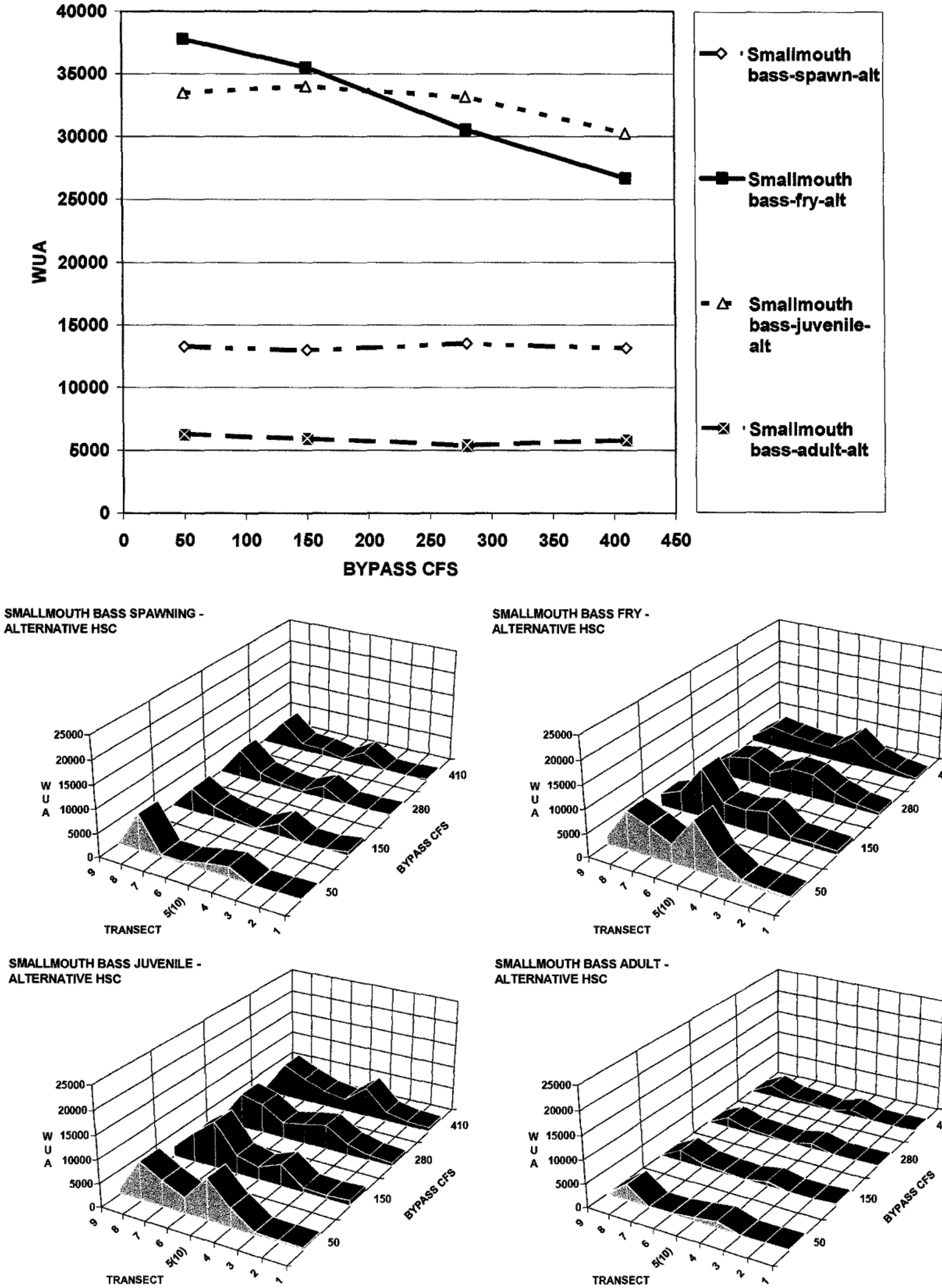
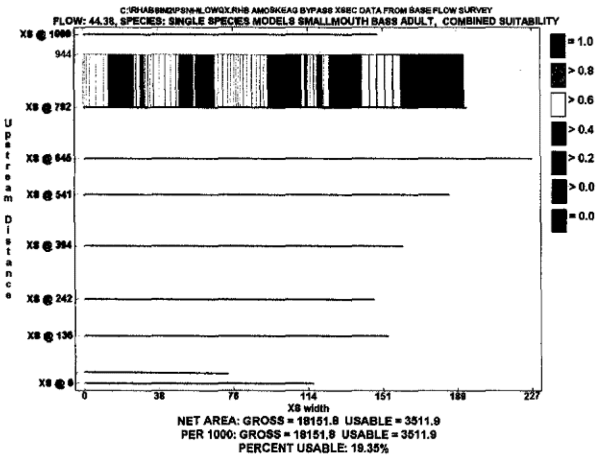
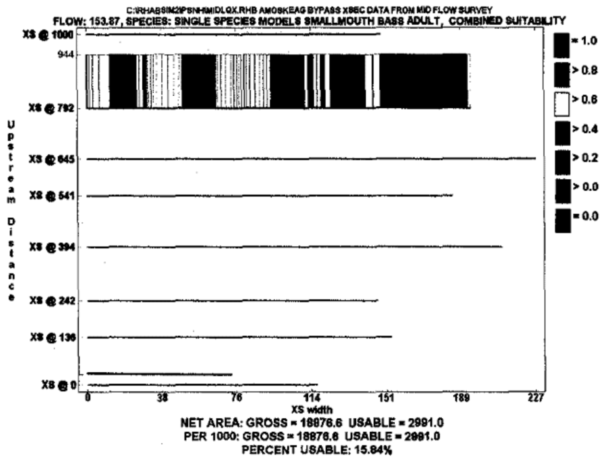


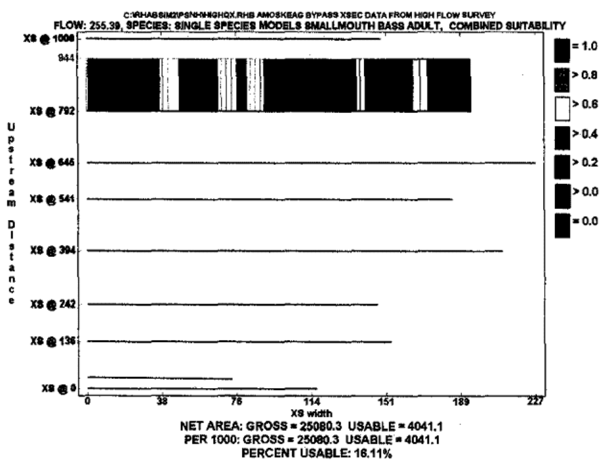
Figure 12. Composite suitability map for smallmouth bass adults (first HSC set) for transect 8 (pool habitat) over the range of test flows. Local discharge levels in panel subtitles are the apparent flows calculated from observed depth and velocity data.



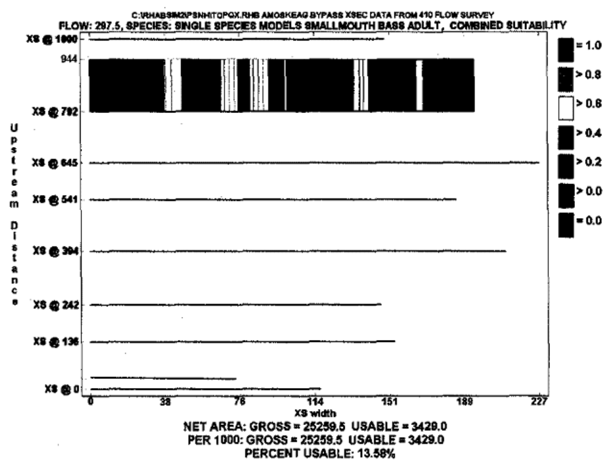
50 cfs



150 cfs



280 cfs

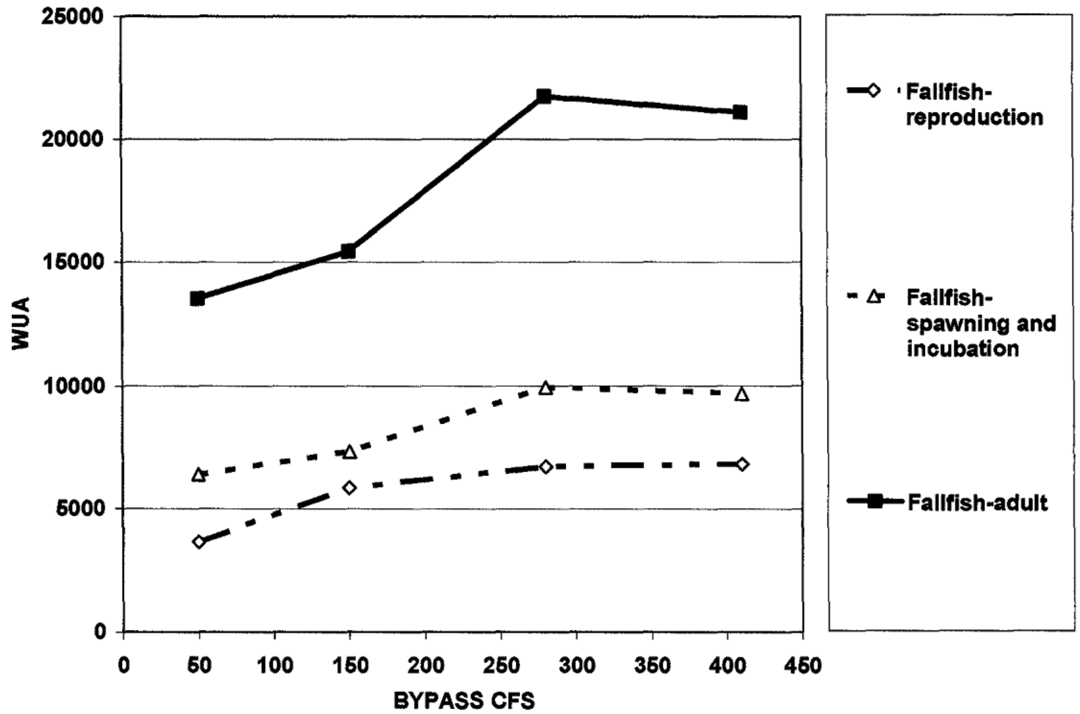


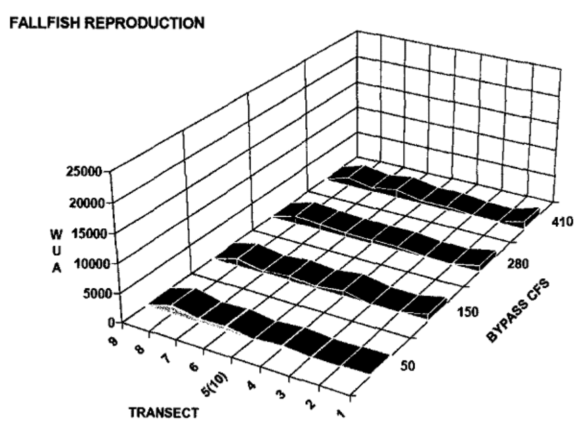
410 cfs

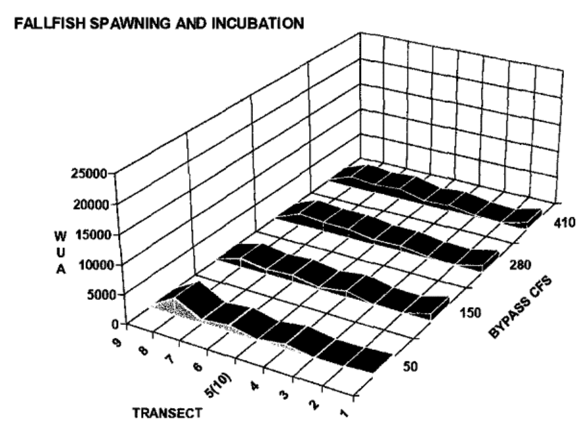
a plateau for adults and a modest peak for juveniles (again reflecting increased tolerance to velocity and depth with age and size).

Spawning habitat was concentrated at transect 7 at 50 cfs but became more diffusely distributed throughout the bypass as test flows increased, reflecting replacement of a small area with higher quality conditions by large areas of less-suitable, but not intolerable habitat. Similar types of change occurred with the WUA metric for common shiner fry. It is unclear whether the decline in fry and juvenile WUA between transect 5 at 50 cfs and transect 10 at 150 cfs was driven more by the change of transect location within the mesohabitat unit or by the increase in discharge.

Figure 13. Upper panel: flow versus WUA relationships for three life stages of fallfish for the entire Amoskeag bypass. Middle and lower panels: relationships by transect representing meso-scale habitat variation within the bypass.







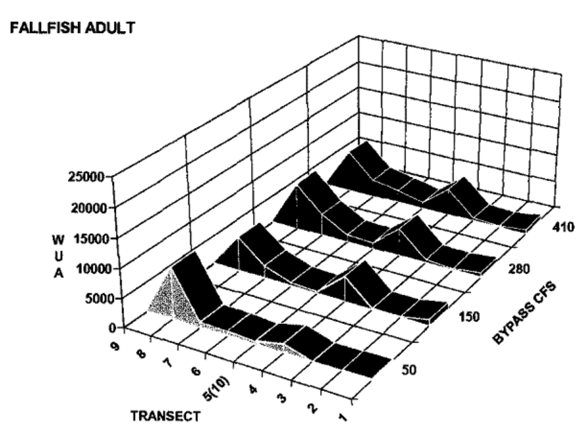


Table 3. Number of RHABSIM model cells with suitability > 0.6 for channel index (PCA CLASS) denoting substrate (S) quality for fallfish spawning, and the number of cells with joint suitability > 0.6 remaining after considering depth (D) and velocity (V) criteria, for the 410 cfs test flow.

Transect	Proportion of reach	S > 0.6	DVS > 0.6
1	0.030	33	22
2	0.106	2	0
3	0.106	3	0
4	0.152	0	0
5(10)	0.147	10	1
6	0.104	5	2
7	0.147	1	0
8	0.152	0	0
9	0.056	0	0

Transect 7, which carries all of the flow exiting the east side of the bypass, consistently provided the most WUA for adult common shiners at all test flows. Constraints on habitat suitability for adults at transect 4 diminished with increasing test flow, but the overall difference between 280 cfs and 410 cfs involved offsetting gains and losses in WUA among various locations; the slightly higher net value at 410 cfs is too small to exceed measurement and sampling uncertainty.

Longnose Dace

Flow-versus-WUA relationships for three life-stages of longnose dace are presented in Figure 15. WUA for longnose dace fry varied little over the range of test flows, and was less constrained by lower velocities at 50 cfs and 150 cfs than WUA for juveniles and adults. Constraints on habitat at 50 cfs were greatest for juveniles, and decreased monotonically with increasing test release for both juveniles and adults. Relaxation of constraints on habitat availability with increasing flow was greater for adults than for juveniles, and occurred slightly more rapidly between 150 cfs and 280 cfs.

Similar to the pattern observed for adult common shiners, transect 7 provided consistently more WUA for all life stages of longnose dace at all test flows except for fry at 410 cfs, for which transect 4 generated the most WUA. Overall, the changes in stream physical conditions, when filtered through the lens of HSC for longnose dace, were somewhat more pronounced between 150 cfs and 280 cfs than between 50 cfs and 150 cfs, or between 280 cfs and 410 cfs.

Spawning Criteria for River Herring

As Figure 16 shows, the relationship between WUA and test flow was bi-modal for river herring spawning criteria, with an initial peak at 50 cfs followed by a moderately higher peak at 280 cfs. Much of the WUA at 50 cfs was generated by transects 7 and 8. Conditions at transect 4 became less constraining as flow increased from 50 cfs to 150 cfs and then to 280 cfs.

Figure 14. Upper panel: flow versus WUA relationships for four life stages of common shiner for the entire Amoskeag bypass. Middle and lower panels: relationships by transect representing meso-scale habitat variation within the bypass.

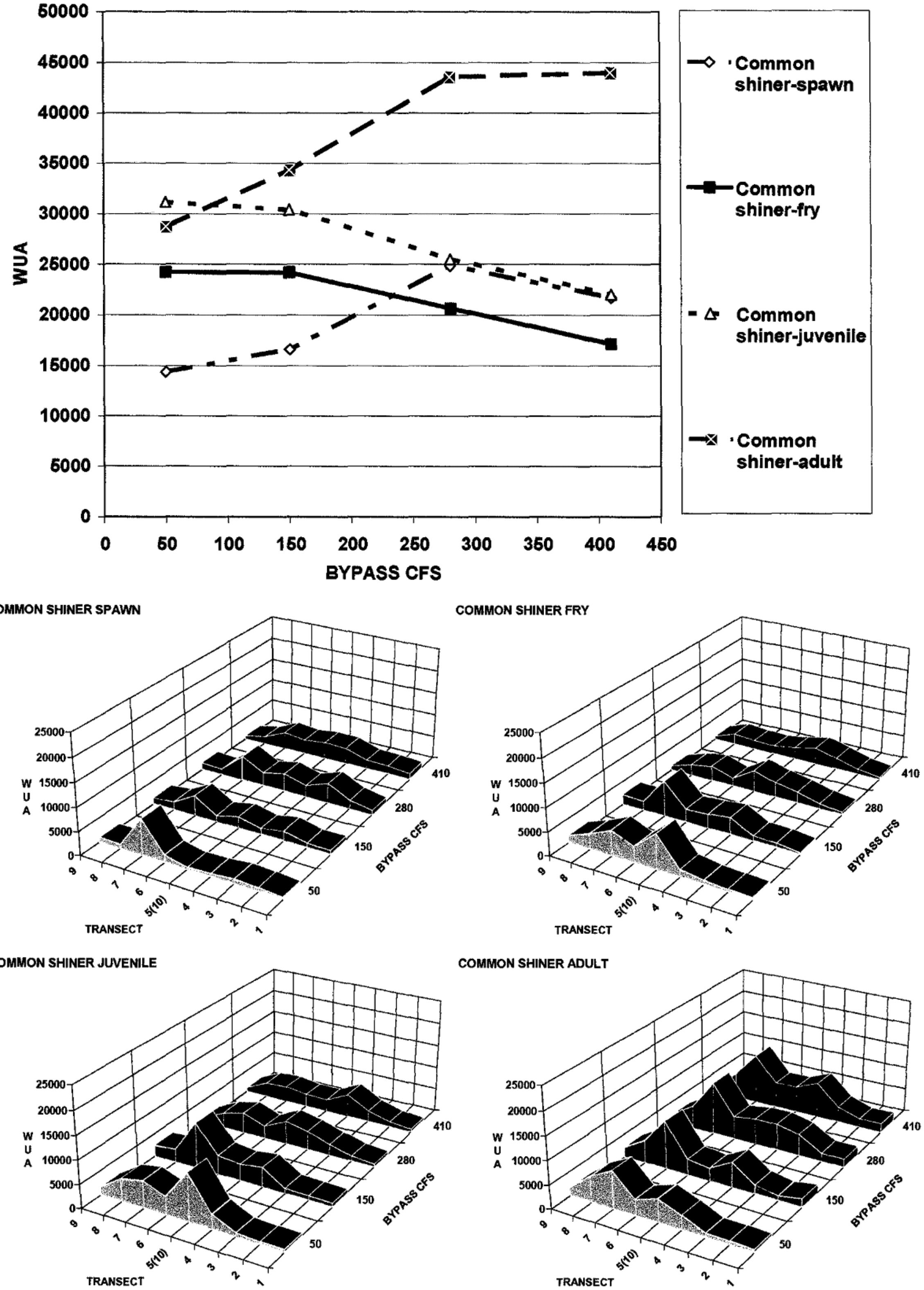
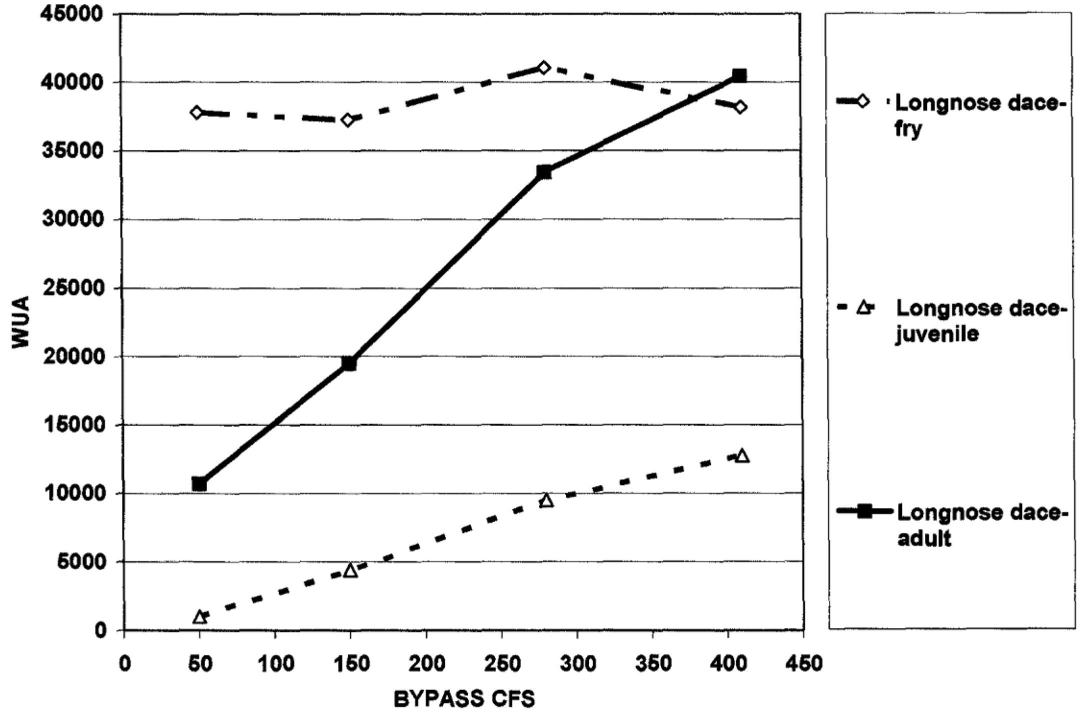
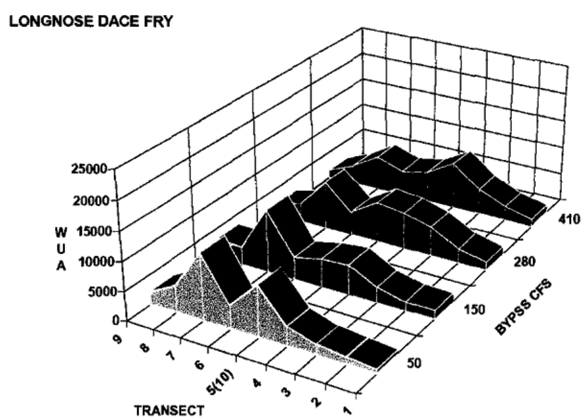
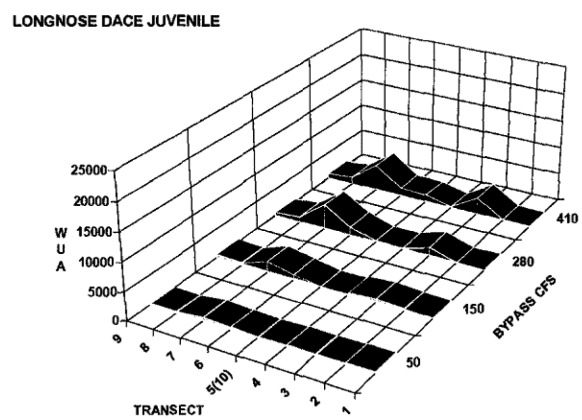


Figure 15. Upper panel: flow versus WUA relationships for three life stages of longnose dace for the entire Amoskeag bypass. Middle and lower panels: relationships by transect representing meso-scale habitat variation within the bypass.







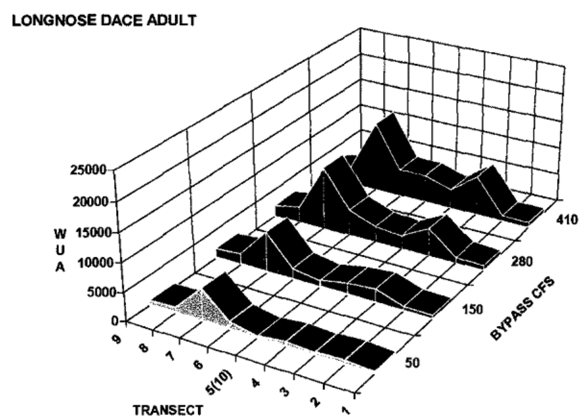
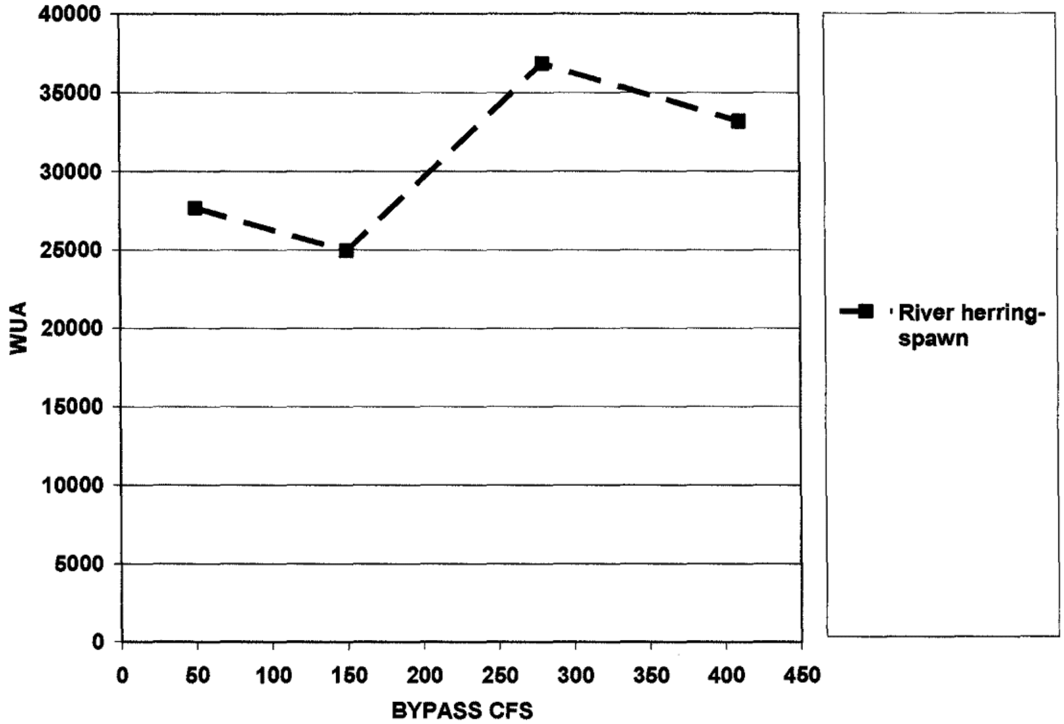
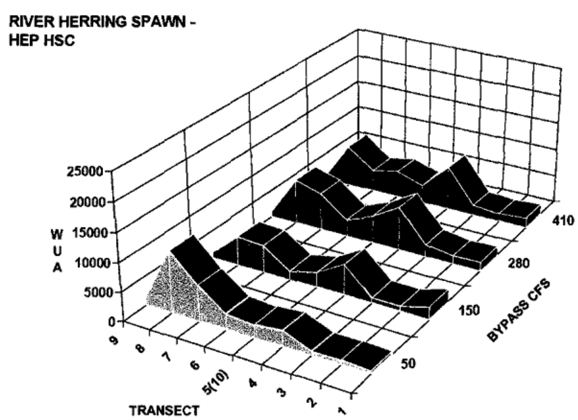


Figure 16. Upper panel: flow versus WUA relationships river herring spawning for the entire Amoskeag bypass. Lower panel: relationships by transect representing meso-scale habitat variation within the bypass.





Corrections to Previously Reported Information

The corrections to velocities to achieve a monotonic increase in partial discharge with increasing test flow required re-computation of WUA for transect 2 at the 280 cfs test release. These changes, and the bypass totals that they also affect, are presented in Table 4 for purposes of study documentation. Values reported in the above analyses are all based on the changes to field data discussed earlier on pages 3 and 4 of this addendum.

Table 4. Corrected values of WUA at the 280 cfs test release based on revisions to field velocity measurements at transect 2.

Evaluation Criteria	WUA (T-2) Original	WUA (T-2) Revised	Bypass Total Original	Bypass Total Revised	Difference (now-then)
Benthic macroinvertebrates					
Ephemeroptera	1530	1824	37919	38213	294
Plecoptera	328	441	16851	16964	113
Trichoptera	1300	1463	37564	37727	163
General Diversity	1048	502	9994	9448	-546
Smallmouth bass					
spawn	48	99	12721	12772	51
spawn-alt	53	109	13444	13500	56
fry	864	1353	30240	30729	489
fry-alt	836	1196	30190	30549	360
juvenile	563	812	30716	30966	250
juvenile-alt	803	1159	32770	33126	356
adult	5	10	5688	5692	4
adult-alt	3	13	5382	5392	10
River herring					
spawn	780	1458	36143	36821	678
Common shiner					
spawn	1151	1939	24064	24852	788
fry	856	1159	20346	20648	302
juvenile	861	1189	25171	25499	329
adult	1565	1850	43243	43528	284
Longnose dace					
fry	1807	2570	40267	41030	763
juvenile	378	27	9828	9477	-351
adult	1534	1069	33900	33436	-465
Fallfish					
reproduction	63	130	6647	6714	67
spawning and incubation	114	130	9924	9941	16
adult	174	246	21667	21739	72
Key habitat types					
shallow-coarse	4259	4259	56828	56828	0
shallow-slow	3045	4031	49984	50970	986
shallow-fast	228	0	4641	4414	-228
slow-cover	1778	3045	35252	36519	1267
deep-fast	0	0	16848	16848	0

Table 4. Continued.

Evaluation Criteria	WUA (T-2) Original	WUA (T-2) Revised	Bypass Total Original	Bypass Total Revised	Difference (now-then)
Generalized habitat types					
shallow-slow-fine-present	0	0	633	633	0
shallow-slow-fine-absent	0	0	2211	2211	0
shallow-slow-coarse-present	2510	3167	25749	26406	657
shallow-slow-coarse-absent	0	0	13633	13633	0
shallow-medium-fine-present	0	0	176	176	0
shallow-medium-fine-absent	0	0	0	0	0
shallow-medium-coarse-present	885	228	8818	8161	-657
shallow-medium-coarse-absent	0	0	2960	2960	0
shallow-fast-fine-present	0	0	0	0	0
shallow-fast-fine-absent	0	0	0	0	0
shallow-fast-coarse-present	0	0	495	495	0
shallow-fast-coarse-absent	0	0	0	0	0
medium-slow-fine-present	0	0	594	594	0
medium-slow-fine-absent	0	0	3567	3567	0
medium-slow-coarse-present	535	864	14553	14882	329
medium-slow-coarse-absent	0	0	7297	7297	0
medium-medium-fine-present	0	0	712	712	0
medium-medium-fine-absent	0	0	1983	1983	0
medium-medium-coarse-present	329	0	13125	12797	-329
medium-medium-coarse-absent	0	0	2260	2260	0
medium-fast-fine-present	0	0	250	250	0
medium-fast-fne-absent	0	0	411	411	0
medium-fast-coarse-present	0	0	1812	1812	0
medium-fast-coarse-absent	0	0	167	167	0
deep-slow-fine-present	0	0	0	0	0
deep-slow-fine-absent	0	0	874	874	0
deep-slow-coarse-present	0	0	806	806	0
deep-slow-coarse-absent	0	0	7439	7439	0
deep-medium-fine-present	0	0	0	0	0
deep-medium-fine-absent	0	0	1581	1581	0
deep-medium-coarse-present	0	0	0	0	0
deep-medium-coarse-absent	0	0	2432	2432	0
deep-fast-fine-present	0	0	0	0	0
deep-fast-fine-absent	0	0	0	0	0
deep-fast-coarse-present	0	0	0	0	0
deep-fast-coarse-absent	0	0	0	0	0

INTEGRATIVE ASSESSMENT

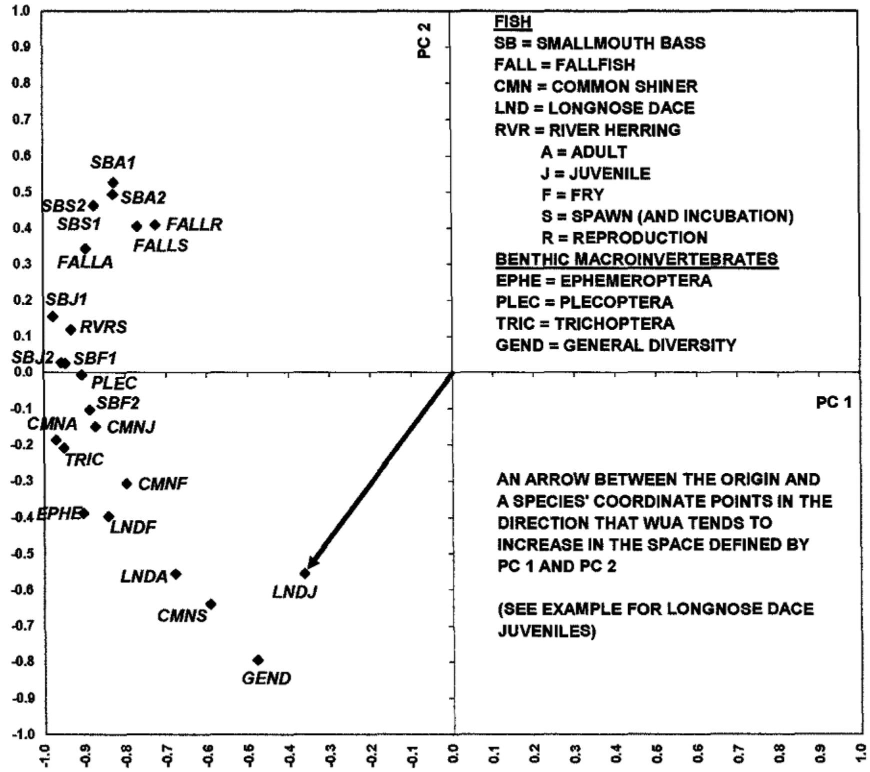
In a study such as this, where there are many evaluation criteria and dimensions of variation to consider (e.g,, several test conditions at multiple locations), integrating results into a common framework for decision-making can be facilitated by analyses that consider the data "all at once" instead of on a case-by-case basis. To provide such a framework, multivariate ordination techniques were used that treated the WUA from each transect, test flow, and species-life stage (or key and generalized habitat type) as response variables. The goal of these analyses was to identify patterns between those responses and environmental classification criteria and in some cases, specific environmental variables. Classification criteria were simply the specific test releases and transects used to identify individual samples. For some analyses, selected hydraulic variables from Table 2 were used as independent predictors of WUA response using a technique called canonical correspondence analysis (CCA), a method of direct gradient analysis that combines elements of ordination and multiple regression statistical models.

CCA constructs ordination axes that are linear combinations of the environmental variables (also known as constrained ordination, Ter Braak and Smilauer 1998), and extracts from a matrix of response variables that part of their variation that is best explained by the selected independent variables. To complement this perspective on the behavior of a multivariable system, methods of "indirect gradient analysis" were used that identify and extract the main directions of variation from just the response matrix. Each ordination axis "explains" (accounts for) a certain fraction of the overall variation in a response matrix, with the first axis explaining the most variation, the second axis explaining the next-greatest amount, and so on. Usually, the main patterns of variation are captured by the first two or three ordination axes. Ordination results are summarized as "axis scores" for both the samples (typically the rows) and the objects whose values vary in magnitude among samples e.g., species and life-stages or other evaluation criteria, which identify the columns of the response matrix. In typical applications on community composition data, species' abundance values or presence-absence data are entered into the body of the matrix, but here, WUA for each evaluation case at each transect and test flow was used.

Ordination methods are available for situations where the changes in response variables with respect to the environmental gradients that structure the responses are either linear or unimodal (hump shaped). Techniques applicable to both types of response were used in this study because changes in WUA with increasing test flow were approximately linear in some cases and unimodal in others. Although each type of model will give somewhat different results, they often produce qualitatively similar patterns that support similar interpretations. Just as HSC act as differential filters that change WUA associated with the same set of environmental observations, use of different ordination models also provide alternative perceptions of system behavior.

The first analysis presented is a PCA of the matrix of WUA values organized by transect and test flow condition (Figure 17). The first axis explained 69.5 % of the variance in the WUA matrix and the second axis explained an additional 15.7 % (85.2 % combined). Correlations > 0.50 in absolute value between sample scores and hydraulic variables in Table 2 were used to interpret these two axes. Specifically, as scores along axis 1 increase, the variables partial discharge, wetted cell number, wetted perimeter, cross-sectional area, top width, hydraulic radius, and average depth decrease. As scores along axis 2 increase, the variables hydraulic radius and average depth increase, and average velocity decreases. These correlations are useful for envisioning physical habitat differences among transects and test flows in the second and third panels of Figure 17.

Figure 17. Principal components analysis (PCA, linear response model) of WUA variation. First panel: species scores (correlations with PC 1 and PC 2). Second: sample scores grouped by transect. Third: sample scores identified by transect and grouped by test flow (next page).



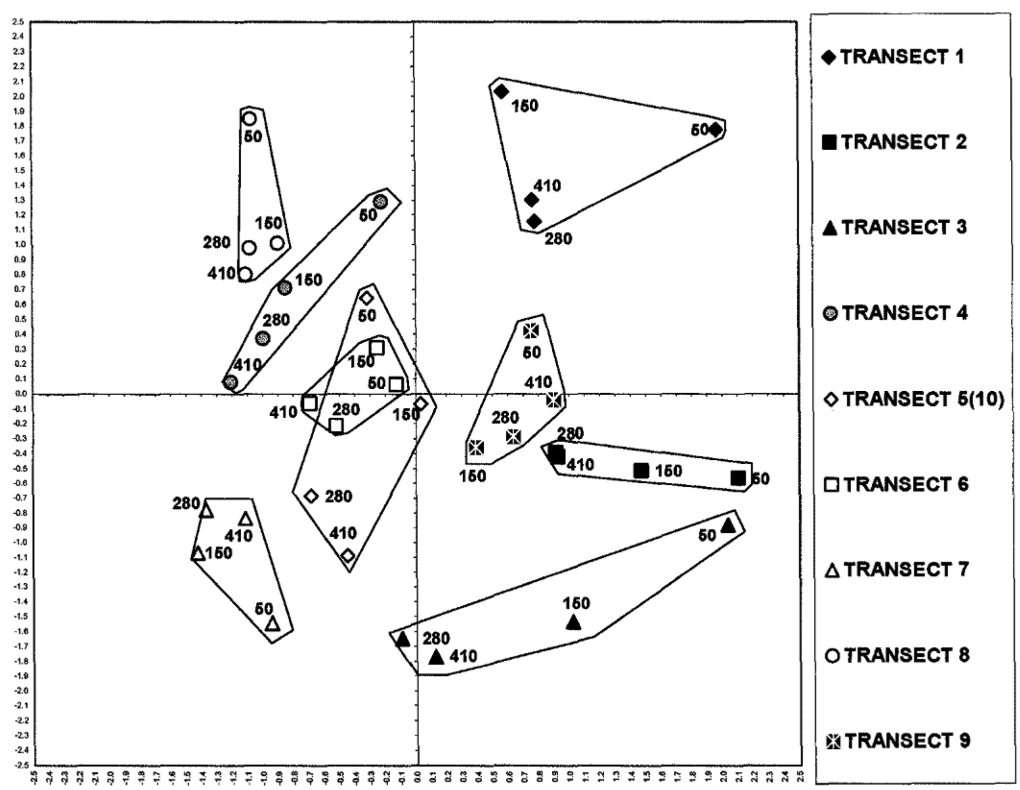
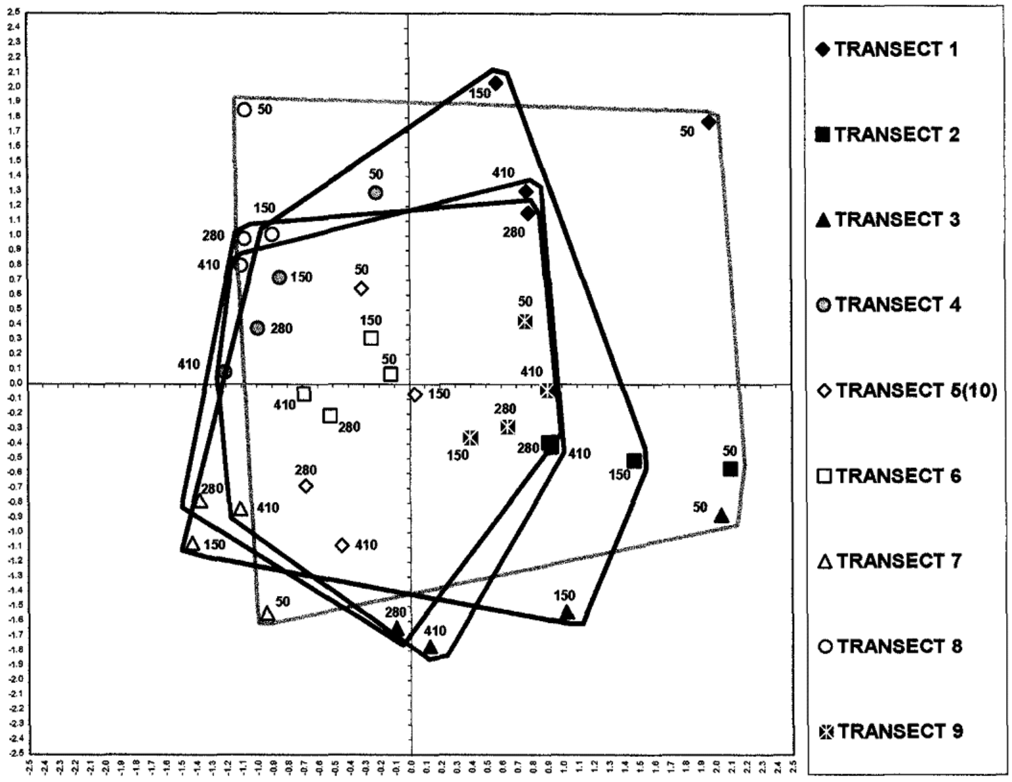


Figure 17. PCA of WUA continued. Polygons enclose samples from the same test flow.



Correlations between the individual cases ("species scores") and the axes are shown in a factor loading plot in the first panel, and identify how well each case is associated with the directions of habitat change reflected in transects and test flows. Because all of the species arrows are pointing toward the left (the decreasing direction on axis 1), it can be inferred that WUA generally increases as the magnitudes of the associated hydraulic variables increase, thus showing a general pattern of increasing habitat availability with increasing stream size, which in turn increases with test flow. The offsetting of species scores along axis 2 (away from the horizontal axis) reflects associations between species and pool versus riffle-like conditions. For example, adult and spawning smallmouth bass cases have the strongest positive associations with axis 2, which indicates increasing average depth and hydraulic radius, and a decrease in average velocity. WUA for both cases was clearly concentrated in pool areas at transect 8 and/or 4 (Figures 10 and 11). Furthermore, WUA for fry and juveniles was not as strongly associated with axis 2, and WUA for those cases was less concentrated in pool areas. In contrast, cases pointing toward the negative side of axis 2 are associated with samples having high average velocity; all have HSC that denote a rheophilic (associated with current) orientation.

From a water management perspective, the third panel shows two important features. First, the local habitat variation among transects obviously interacts in a complicated matter with test flow when viewed through the filters of multiple evaluation criteria. Second, the overall state of the system tends to change in an orderly fashion as test flow increases from 50 cfs to 280 cfs, but the configuration changes little between 280 cfs and 410 cfs. Although the directions of change on the physical page are different, the correlations between the PCA axes and hydraulic variables denote relative relationships among test flows that are qualitatively very similar to the PCA ordination of just the hydraulic variables presented earlier in Figure 3. The main difference is that while hydraulic conditions continued to change in a progressive fashion as test flows increased, the response of the system reached a plateau when viewed through the filter of a diverse set of evaluation criteria. This suggests that a general shift in the behavior of the constraint system (see Box 1 earlier) occurs somewhere in the vicinity of 280 cfs. That is, by and large, the overall growth in WUA keeps pace with the increase in total wetted area up until that point, but at 410 cfs, gains in some areas are offset by losses in others. This aspect of the constraint system can also be seen in the differences in the sum of all WUA totals over various sets of evaluation cases computed for each test flow, and in their rate of change per cfs (Table 5). Expression of these totals as a percentage of total area, when subtracted from 1.0, provides a means to rank evaluation criteria in terms of their overall degree of constraint imposed by the series of test flows, which gives an indication of the sensitivity of the environmental filter imposed by various HSC. In this view, river herring spawning is the least constrained criterion, and fallfish are the most.

The remaining analyses all tell pretty much the same story as the PCA ordination, even though they are based on different response models and types of gradient analysis. Note that physical directions of change vary between diagrams with respect to the identities of sample scores, which is unimportant. It is the relative positions of samples with respect to each other that give meaning to their positions along ordination axes. Figure 18 is a detrended correspondence analysis (DCA) of the same matrix of WUA values analyzed in Figure 17. In particular, note the emergence of similar relationships among sample scores grouped by test flow. In this analysis, constraints on WUA imposed by differences between riffle-like cross-sections and pool-like cross-sections is emphasized on the first axis, while differences among test flows are clearly expressed along the second axis.

Although the physical ordering of the first axis is reversed in the subsequent direct analysis based on CCA (Figure 19), similar relationships emerge when the ordination axes are derived directly from hydraulic variables. Note than in this analysis, a forward selection process was used to reduce the number of variables in the model. Many of the hydraulic variables were strongly correlated with each other. Choosing only one of each set of highly correlated variables in the system reduced multicollinearity in the construction of the axes. The variables chosen (shown by the arrows in Figure 18) were the ones that were significantly associated ($p < 0.05$) with variation in the response matrix as judged by a built-in randomization test in the CANOCO software program used to perform the analysis.

Focus switches from biological to physical criteria in the last two analyses. Figure 20 is a CCA of key and generalized habitat types in relation to a set of hydraulic variables selected in the same manner as the preceding analysis. Note that although the names of the types are defined using segments along depth and velocity axes, their positions in the first panel bear only a weak correspondence to the environmental arrows for average velocity and average depth, for example. This is because the areas of these types are also influenced by cover and substrate factors that are not represented in the explanatory environmental data. Despite this, the orientation of polygons enclosing scores from the same test flow retained the relationships among one another that were revealed by other methods. The same is true of an indirect analysis (PCA) of the same dependent matrix based on a linear response model (Figure 21).

Table 5. Totals of WUA over different sets of evaluation cases at each test flow reflect changes in the governing system of constraints imposed by the particular cases and their HSC chosen for study.

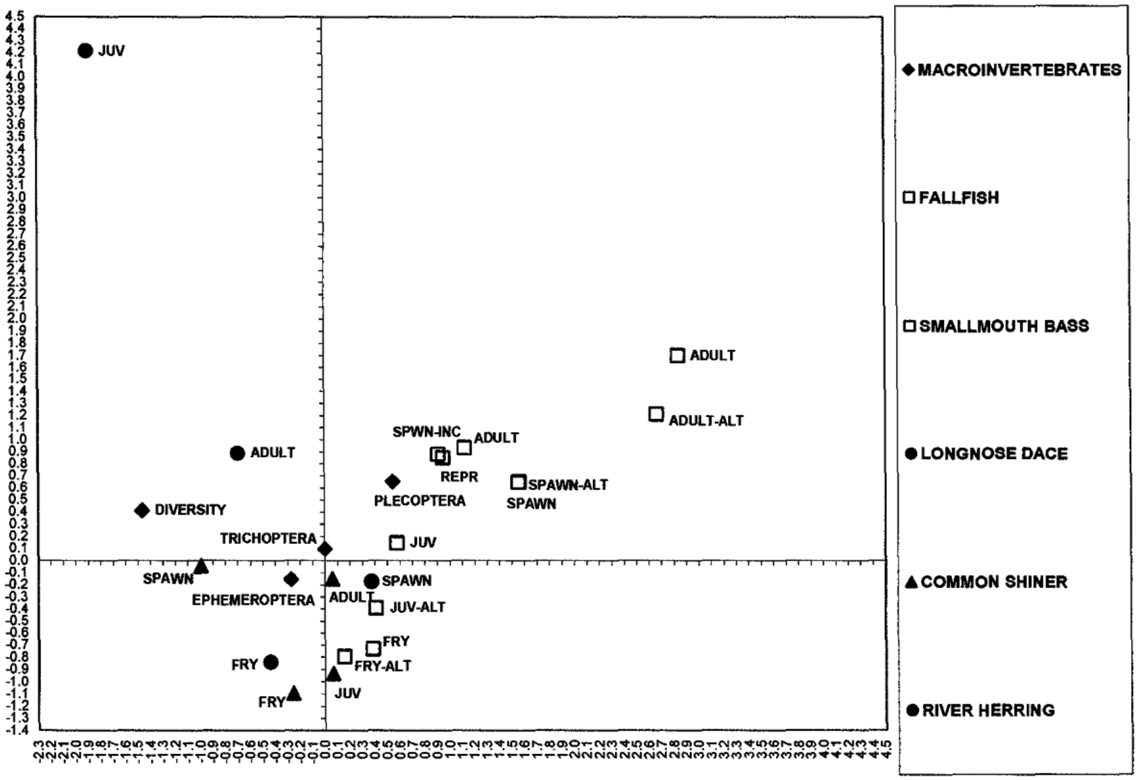
		Test Flow	A sum (WUA)	B sum(Area)	Proportion (A / B)	Degree of constraint (1-Proportion)
Total system (all evaluation cases including generalized habitat types not shown here)						
(case 1)		50	616626	4710572	0.131	0.869
change per cfs	825	150	699167	5935553	0.118	0.882
	921	280	818879	7330433	0.112	0.888
	-24	410	815740	7769764	0.105	0.895
					mean:	0.884
Benthic macroinvertebrates						
(case 2)		50	57230	294411	0.194	0.806
change per cfs	188	150	76040	370972	0.205	0.795
	202	280	102352	458152	0.223	0.777
	52	410	109155	485610	0.225	0.775
					mean:	0.788
Key habitat types						
(case 3)		50	125199	368013	0.340	0.660
change per cfs	227	150	147865	463715	0.319	0.681
	136	280	165578	572690	0.289	0.711
	20	410	168209	607013	0.277	0.723
					mean:	0.694
Smallmouth bass (first set of HSC)						
(case 4)		50	70835	294411	0.241	0.759
change per cfs	33	150	74146	370972	0.200	0.800
	46	280	80159	458152	0.175	0.825
	-45	410	74325	485610	0.153	0.847
					mean:	0.808
Longnose dace						
(case 5)		50	49404	220808	0.224	0.776
change per cfs	116	150	60985	278229	0.219	0.781
	177	280	83943	343614	0.244	0.756
	56	410	91264	364208	0.251	0.749
					mean:	0.766
Fallfish						
(case 6)		50	23565	220808	0.107	0.893
change per cfs	50	150	28602	278229	0.103	0.897
	75	280	38394	343614	0.112	0.888
	-6	410	37576	364208	0.103	0.897
					mean:	0.894
Common shiner						
(case 7)		50	98431	294411	0.334	0.666
change per cfs	71	150	105483	370972	0.284	0.716
	70	280	114527	458152	0.250	0.750
	-75	410	104836	485610	0.216	0.784
					mean:	0.729
River herring spawn						
(case 8)		50	27607	73603	0.375	0.625
change per cfs	-26	150	24960	92743	0.269	0.731
	91	280	36821	114538	0.321	0.679
	-28	410	33189	121403	0.273	0.727
					mean:	0.690

Ordering of constraints by evaluation case

8 < 3 < 7 < 5 < 2 < 4 < 1 < 6

River herring Fallfish

Figure 18. Detrended correspondence analysis (DCA, unimodal response model) of WUA variation. First panel: species scores. Second: sample scores grouped by transect. Third: sample scores identified by transect and grouped by test flow (next page).



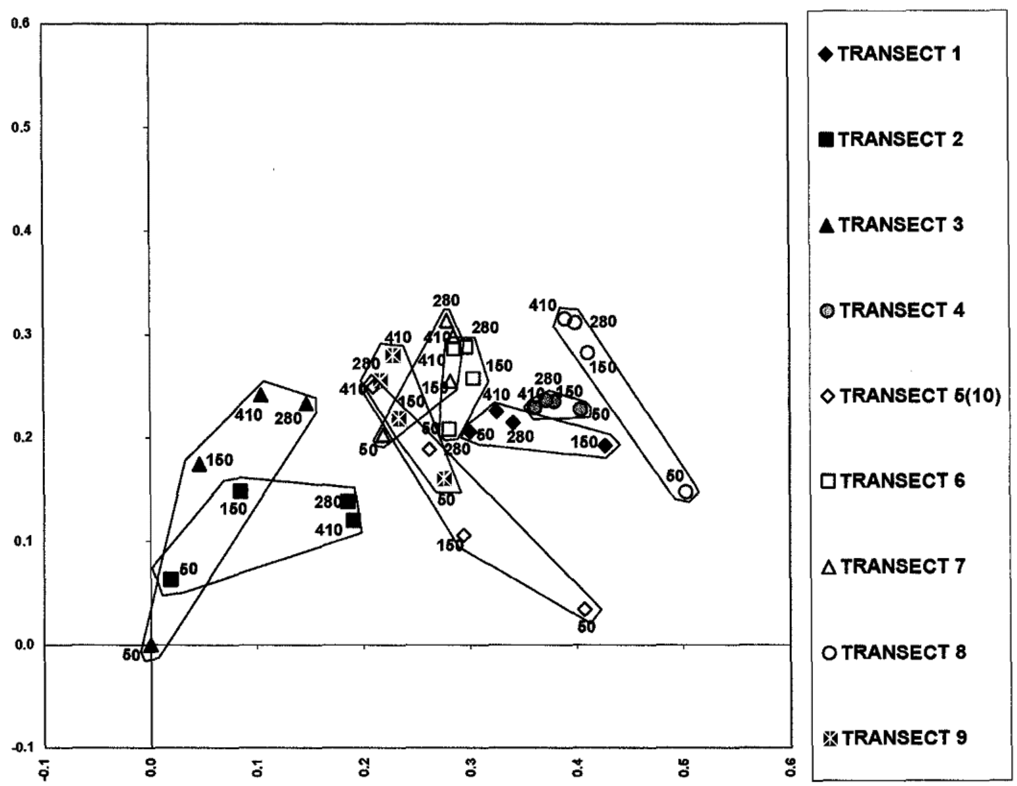
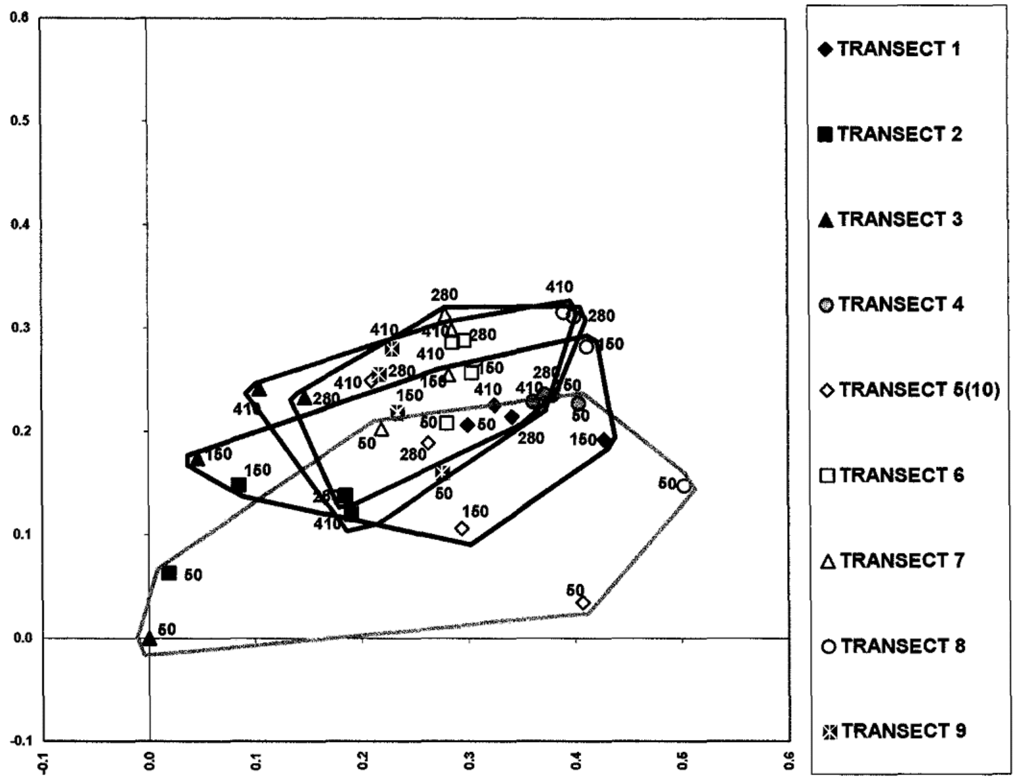


Figure 18. DCA of WUA continued. Polygons enclose samples from the same test flow.



CONCLUSIONS

The foregoing study (including results presented in the primary report) has provided an in-depth analysis of habitat variation in the Amoskeag bypass as viewed with a diverse set of evaluation criteria. However, this variation is still couched within the context of an evaluation of static conditions provided by increments of increasing test flow into the bypass. Thus, the results only bear witness to one aspect of the manner in which habitat influences resident aquatic biota. In particular, the element of temporal variation is completely ignored, and yet there is considerable evidence from the literature that populations and communities of aquatic organisms are strongly patterned by flow regime characteristics (Poff and Ward 1990, Poff and Allan 1995, Poff et al. 1997). In the Amoskeag bypass, the existing flow regime can be characterized as a "two-stage" regime, where a constant low-flow condition is interspersed with episodic spills of much higher magnitude that occur when inflow exceeds the capacity of the hydroelectric station.

In many cases, population and community characteristics in riverine environments will reflect the specifics of timing, intensity, and predictability of disturbance, which may cloud or completely negate any differences caused by changes in steady-state flow levels. Yet another set of confounding factors that limit the ability of simple habitat-based models to predict population and community characteristics are the uncertain effects of physiognomy (arrangement) of habitat patches within the defined extent of evaluation, as well as the relationship of that extent to the larger environment within which it is embedded (Allen et al. 1984, Allen and Hoekstra 1992, Ahl and Allen 1996). Thus, while perceptions of physical habitat availability (which are best viewed

Figure 19. Canonical correspondence analysis (CCA) of WUA variation related to hydraulic variables. First panel: species scores and environmental variables. Second: linear combination (LC) sample scores grouped by transect. Third: LC scores grouped by test flow (next page).

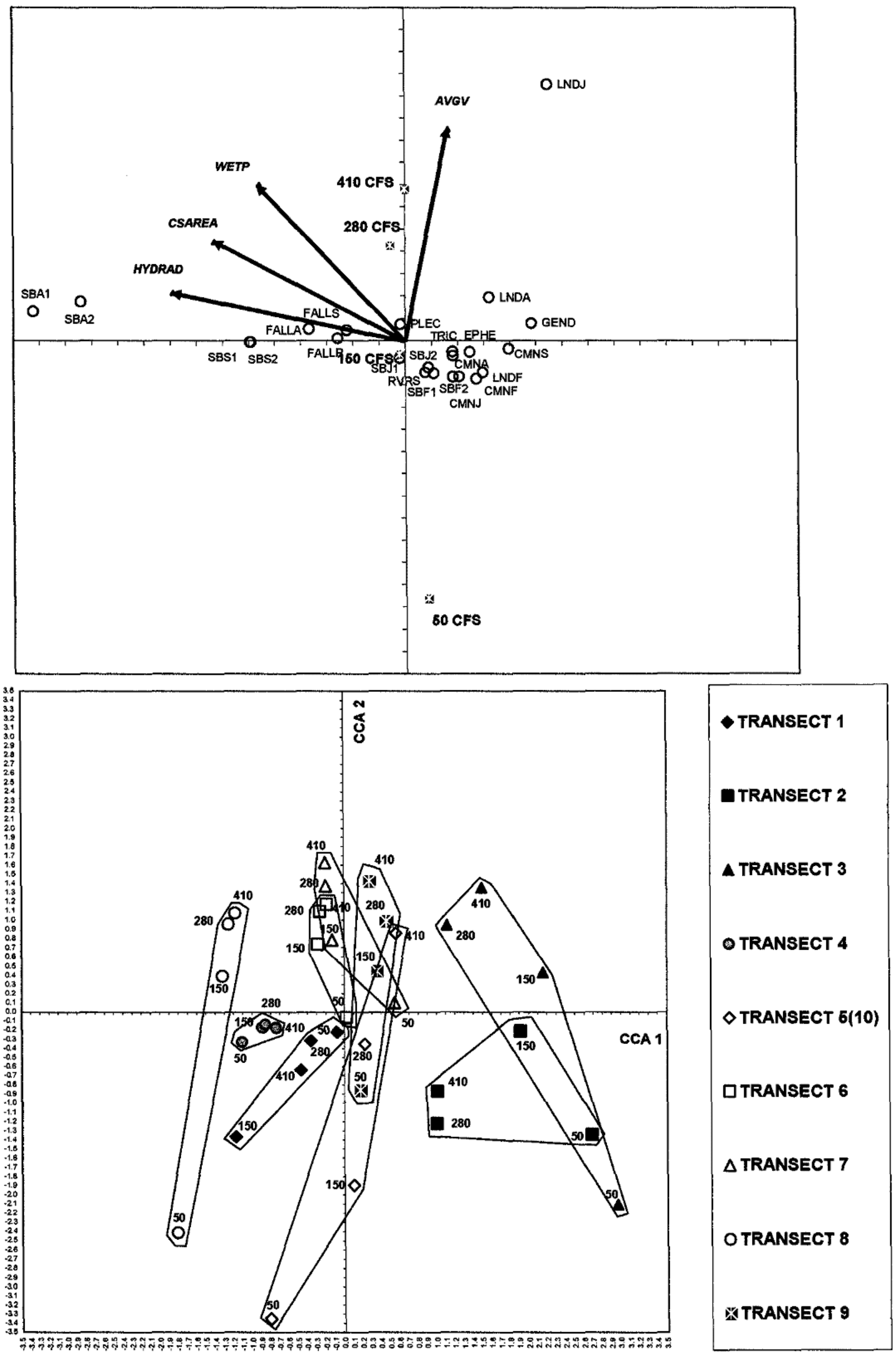
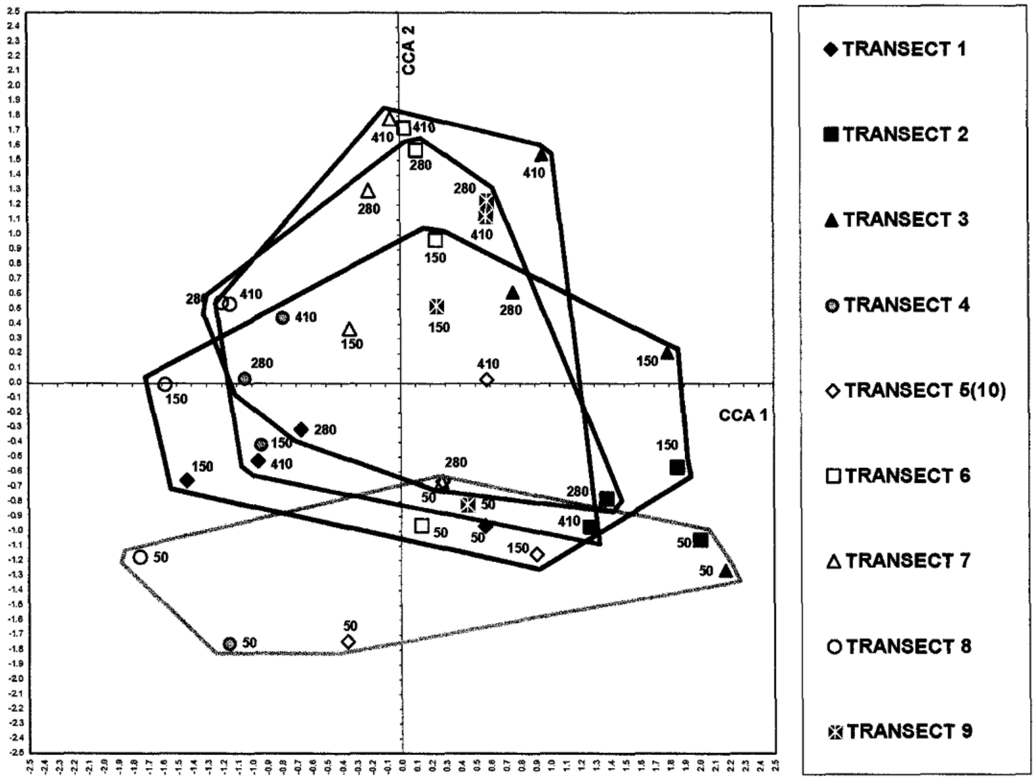


Figure 19. CCA of WUA variation continued. Polygons enclose samples from the same test flow.



as a system of constraint) provide a perfectly legitimate currency for comparison with other values that stem from human use of natural resources, their linkages to biological components of the system are complex, and become more tenuous as more of their constraint system is ignored (e.g., by not accounting for temporal variation).

Be that as it may, results of this study revealed that, within the limits imposed by grain and extent of observational data (four test flows ranging from 50 cfs to 410 cfs), there is little meaningful difference in steady-state habitat constraints imposed on evaluation criteria between 410 cfs and 280 cfs. The most rapid change in the observed portions of the constraint system occurred between 50 cfs and 150 cfs, and differences between 150 cfs and 280 cfs were still observable. Accordingly, decisions on the magnitude of steady-state releases into the bypass should focus on that flow range, and bring into the equation other values associated with recreational, aesthetic, power generation, and safety values, factors that are beyond the scope of this study.

One final note to consider is that while the ability to control the high-flow disturbance regime (identified here as a biologically important factor omitted from this analysis) is constrained by the hydraulic capacity of the Amoskeag station, the opportunity to buffer those disturbances (at least somewhat) can be found in the concept of seasonably variable minimum flows. Effects of flooding on aquatic organisms at localized scales are partially related to the degree of change between the base flow preceding a runoff event and the intensity of the disturbance at its peak. Because spills at Amoskeag are much more likely during the snow-melt period in spring, providing a higher base flow at that time of year would buffer the contrast between low and high

Figure 20. CCA of the areas of key and generalized habit types in relation to hydraulic variables. First panel: scores for types and environmental variables. Second: LC sample scores grouped by transect. Third: LC sample scores identified by transect and grouped by test flow (next page).

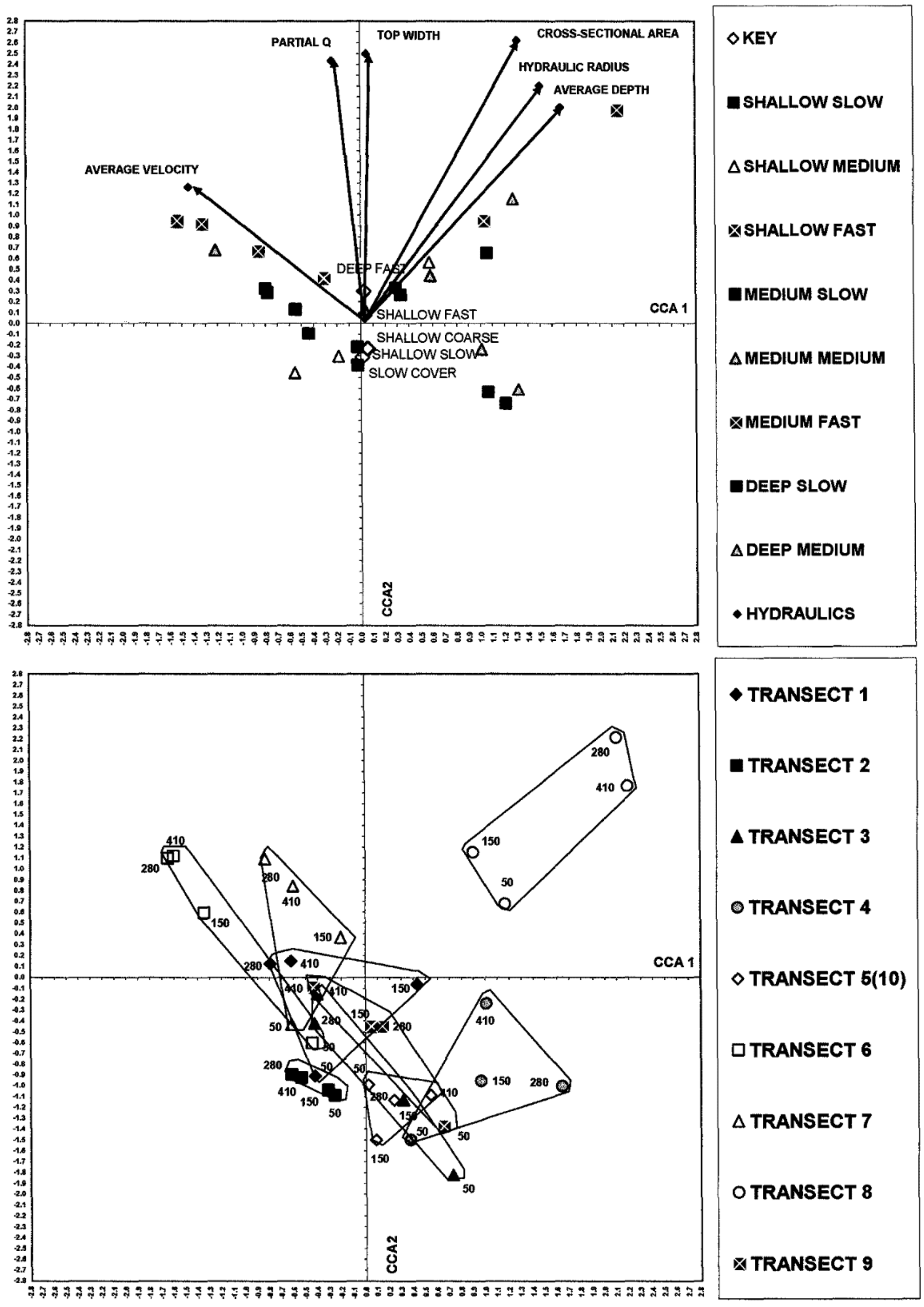
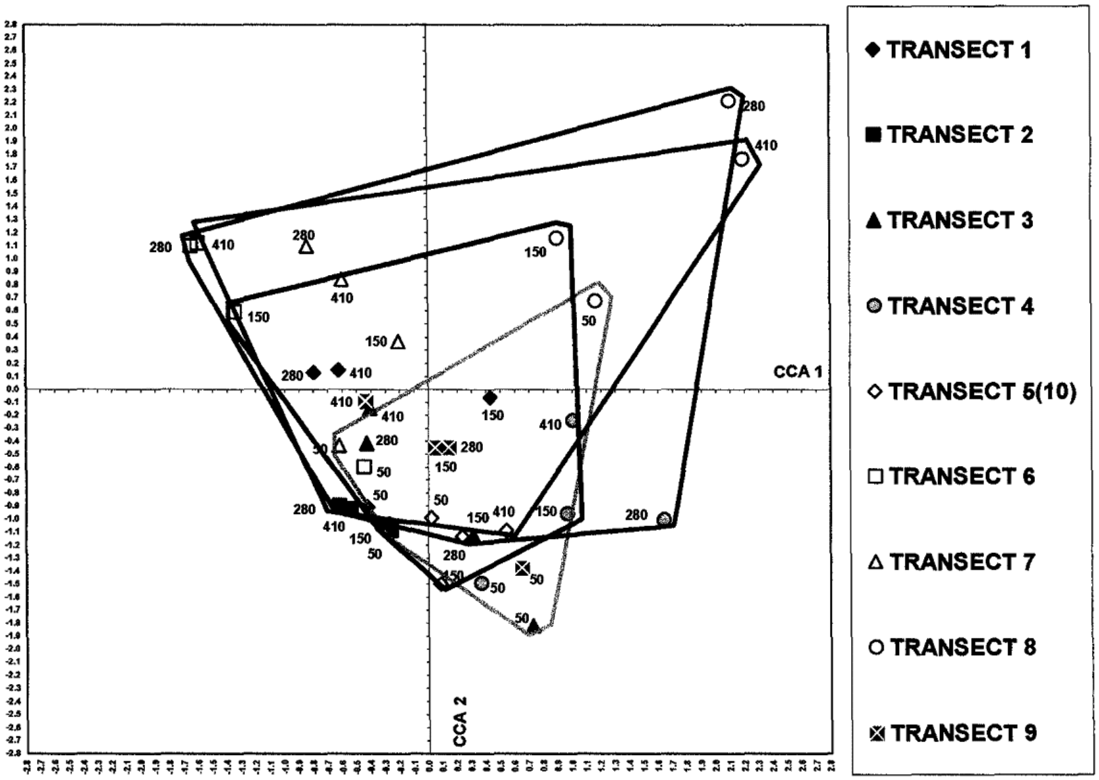


Figure 20. CCA of key and generalized habitat types continued. Polygons enclose samples from the same test flow.



flows at that time. As the probability of a spill decreases into the summer and fall (a typical pattern for New England rivers), minimum flows could be decreased to mimic the timing of natural low-flow periods, which are also functionally important in riverine systems (Poff et al. 1997). This concept could be extended to even shorter time scales by allowing the system to "ramp down" to the minimum flow in a gradual or step-wise fashion following a spill event.

Figure 21. PCA of the areas of key and generalized habitat types. First panel: scores (correlations with PC 1 and PC 2) for habitat types. Second: sample scores grouped by transect. Third: sample scores identified by transect and grouped by test flow (next page).

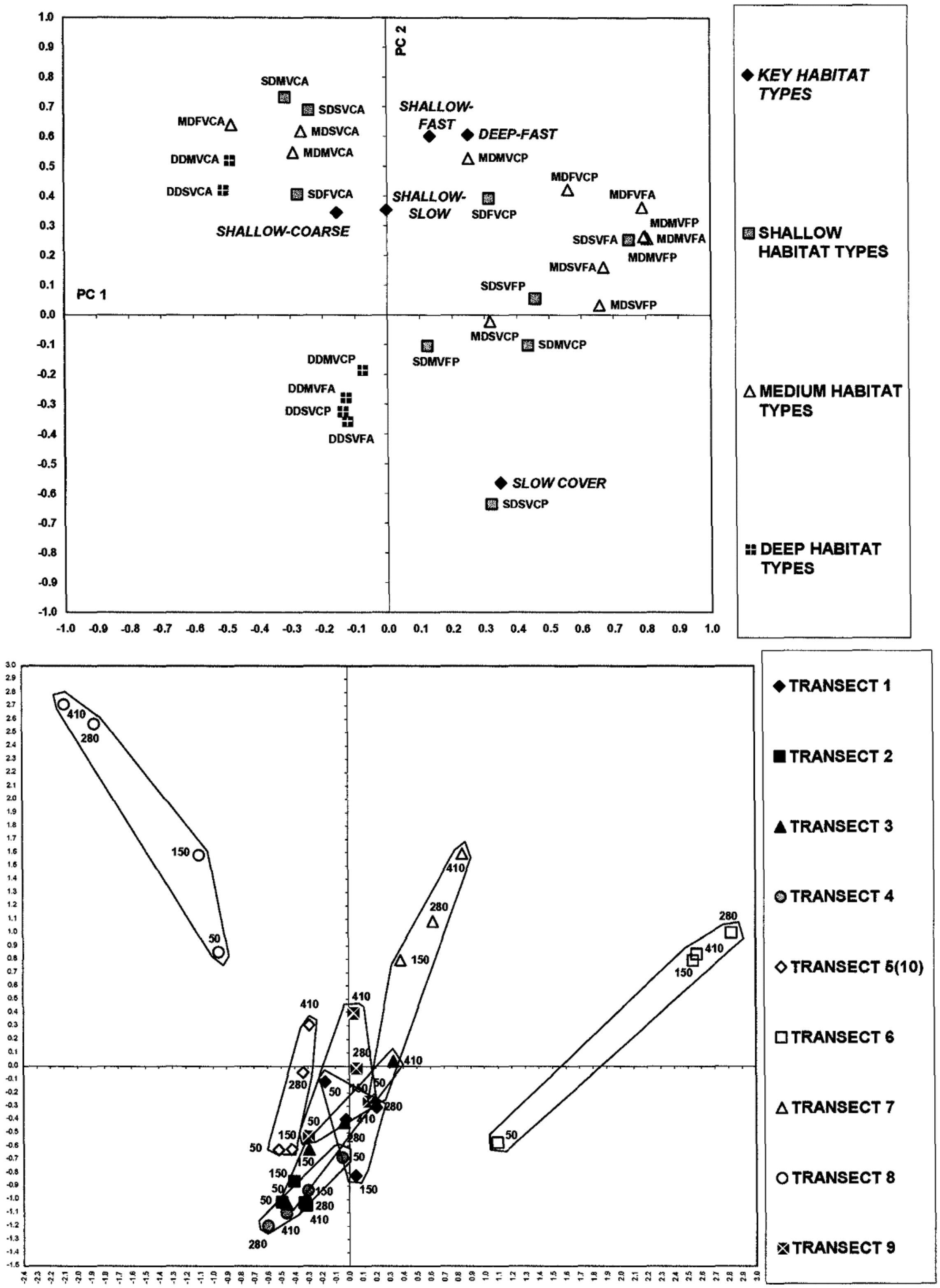
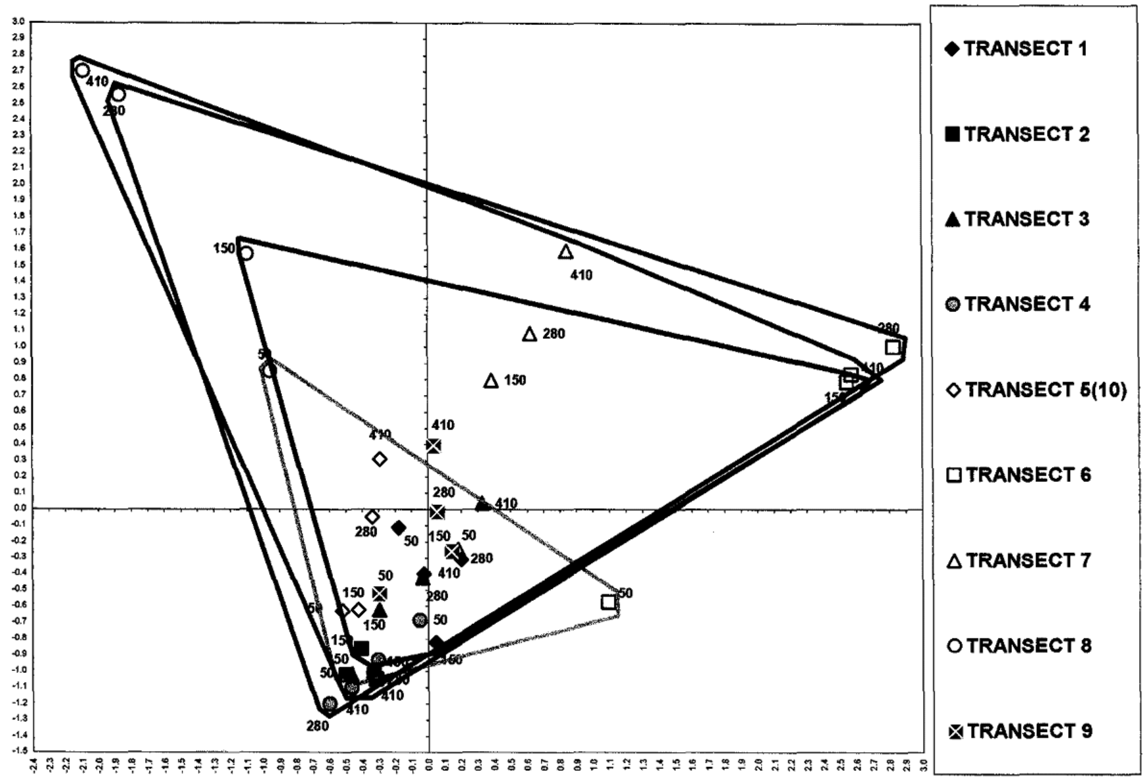


Figure 21. PCA of key and generalized habitat types continued. Polygons enclose samples from the same test flow.



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